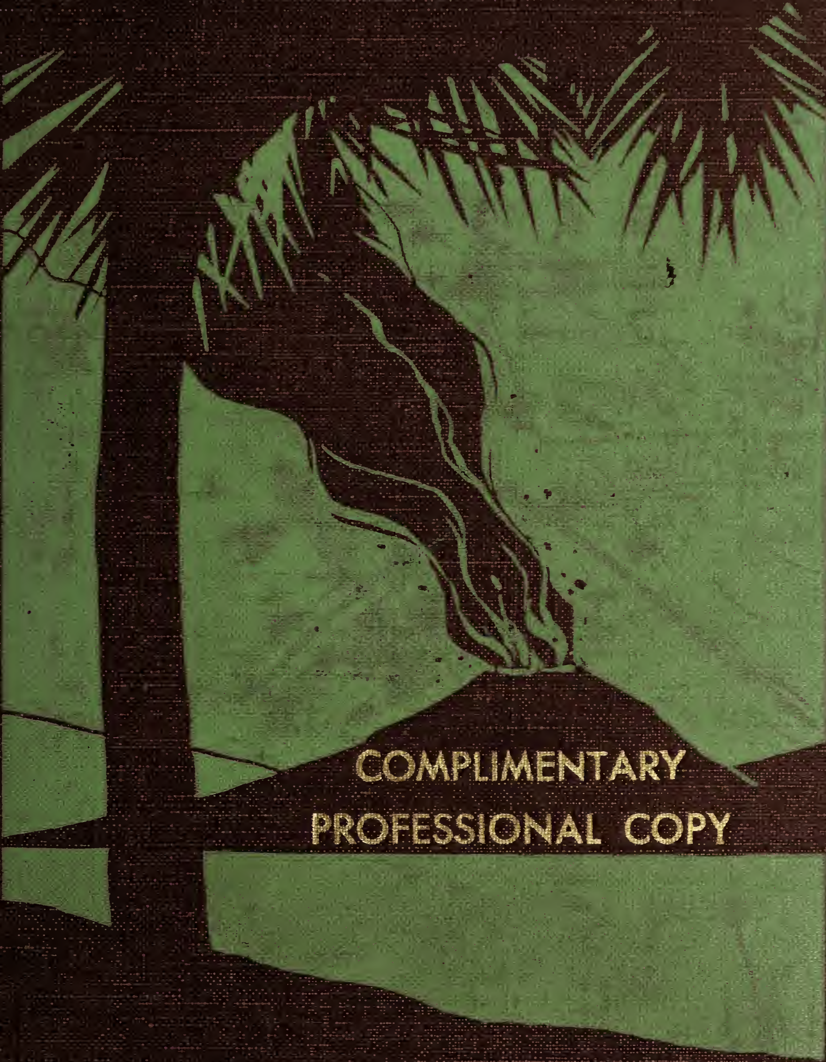
THIS CHANGING WORLD



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A Survey of Science

A three-book series for the junior-high-school grades, embodying the recommendations of the Thirty-first Yearbook. See the preface, pages iii-iv.

II. THIS CHANGING WORLD

Please notice these nine important features:

1. *Its underlying theme:* the changes that are going on in the living and non-living things in the world around us. See the preface, page v.

2. *Its organization into large units of work,* each of which develops an important feature of our changing environment and sets up problem situations which, because of their genuine interest and importance, really challenge the pupil. See the contents, pages ix–xii. The units are arranged in such an order as to give the learner an increasingly enlarged understanding of the major theme of the book.

3. *Its pupil foreword,* which not only explains at the outset the major theme and underlying point of view of the book, but also motivates the pupil's approach. See pages xiii–xiv.

4. *Its unit previews*, which awaken keen interests and establish desirable points of view. See pages 4, 114, 210.

5. *Its smoothly developed chapters*, each of which gives the pupil a picture of some situation that is rich in potentialities for further study. Glance through pages 65–88, 137–157.

6. *Its chapter summaries*, which state simply and concisely the salient principles and facts which the pupil has just studied. See pages 19, 41, 63.

7. *Its wealth of questions and things to do*, which stimulate thought and bring pupils into actual contact with scientific phenomena. See pages 19–21, 42–43, 63–64.

8. *Its useful glossary of science words*. See pages 535–552.

9. *Its abundant illustrations*, which help the pupil materially to visualize what he is studying and assist him in arriving at desired understandings.

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A · SURVEY · OF · SCIENCE · II
FOR JUNIOR HIGH SCHOOLS

This Changing World

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Professor of Natural Sciences
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THE ATHENÆUM PRESS

GINN AND COMPANY
BOSTON · NEW YORK · CHICAGO · LONDON · ATLANTA · DALLAS · COLUMBUS · SAN FRANCISCO

PRINTED IN THE UNITED STATES OF AMERICA

634.8

A · SURVEY · OF · SCIENCE
FOR JUNIOR HIGH SCHOOLS

I. The World Around Us

II. This Changing World

III. Man's Control of his Environment

The Athenæum Press
GINN AND COMPANY · PRO-
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Preface

This series has been prepared for use in the junior-high-school grades. The books are equally appropriate for such use, whether or not the grades are incorporated in a junior-high-school organization.

The authors have been guided in this work by the recommendations set forth in the report "A Program for Teaching Science," in the Thirty-first Yearbook of the National Society for the Study of Education (1932), Part I. In this report it is recommended that:

> The science courses of the seventh, eighth, and ninth grades should be considered as an integral part of the program of science instruction for the period of elementary and secondary education. The science of this level should, on the one hand, be built upon and comprehend the science of the first six grades; it should, on the other hand, serve as a basis for an orientation into the special sciences of the high school for those who are to continue beyond the ninth grade. Above all else, it must provide the most worth-while science experiences possible for the pupils on this level, and it must be in accord with the acceptable objectives of a liberal education for boys and girls of ages twelve to sixteen years.

In this report of the National Society for the Study of Education there is a list of principles and generalizations which, taken collectively, define the major contributions of science to human welfare and to human interests. This list of principles and generalizations, with some additions and modifications, has been used for guidance in the selection of instructional material used in these books.

The series constitutes A Survey of Science. It is an exploratory survey of the areas of scientific achievement defined by the important principles and generalizations. The series is designed to give to children an acquaintance with, and an ability to use, the products of

scientific achievements that are interesting and important in the general, unspecialized, intellectual and practical activities of educated laymen. The criteria set forth in the yearbook in the chapters on "The Objectives of Science Teaching in Relation to the Aim of Education," "The Psychology of Science Teaching," and "Science in the Seventh, Eighth, and Ninth Grades" have been carefully considered in the selection and organization of the instructional material used in these texts.

The point of view developed in this report of the National Society for the Study of Education and accepted in the preparation of this series is that the aim of instruction in science is threefold:

1. To develop an understanding of, together with an ability and desire to use, those scientific attainments that may function in intellectual experiences most common to everybody.
2. To develop some understanding of, together with an ability and desire to use, some of the methods by means of which scientific attainments have been achieved.
3. To engender the scientific attitude of respect for truth and for scientific methods.

It may be expected that the attainment of this threefold aim will function in the lives of maturing youths and in their lives as adults, as a continuous stimulation to wholesome intellectual endeavors and as a constant source of personal satisfaction due to enriched appreciation.

For the attainment of this aim these books furnish a wealth of vicarious experiences and suggestions for actual contacts with challenging scientific phenomena. At the end of each chapter there are many carefully prepared aids to learning which take the form of direct experiences. These are arranged under the following heads: "Can You Answer these Questions?" "Questions for Discussion," and "Here are Some Things You May Want to Do." These direct and vicarious experiences supplement one another in developing for the learner a continuous enlarge-

ment of understanding of important principles and generalizations, and serve to develop an increasing ability to use scientific methods of work.

The one theme that runs through these books is "Living things — including man — are dependent upon one another and upon the physical environment." The course develops an understanding of the ways in which this dependence functions. In the first book of the series (*The World Around Us*) emphasis is placed upon getting acquainted with the environment. The second book recognizes as a major theme the changes that are going on in living and nonliving things. In the third book the emphasis is upon control of physical and biological phenomena. These three features — acquaintance, change, and control — find recognition in each book, but the progress throughout the series is toward an increasingly intensive study of controls and an enlarged understanding of the extent to which man has broken the boundary of space and time in his efforts to attain a more satisfying adaptation to his environment and a fuller understanding of his place in the cosmos.

Experiences of exploration and adventure, similar to those associated with camp life, field work, club activities, and travel, have been used extensively in the writing. The experiences told in the text serve to enrich the activities associated with the recreational features which come normally into the lives of pupils of junior-high-school age and which constitute such an important part of their educational program. This is especially timely, since these youths will doubtless have, as adults, larger opportunities for recreational activities than any preceding generation has ever enjoyed.

Throughout the series there is a continuous development of understanding of the positive aspects of health. These have to do with the proper functioning of the normal and vigorous human body. Such understanding aids the pupil to acquire respect for his own most precious possession.

The need for corrective measures in the control of health is recognized in the chapters that develop the procedures for control of bacterial and other forms of parasitic organisms that cause disease, and in the chapters that show the relations of foods to health. The field of health offers illustrations of the manner in which science has contributed to the development of modern standards of living. The importance of sanitary measures and the penalties of ignorance in the form of illnesses with attendant losses to the community are well known. The science of sanitation has shown us how to protect crowded cities and rural communities from contagious diseases which, if uncontrolled, would be terribly destructive. Throughout these books may be seen a continuous development of scientific concepts that are functional in the thinking associated with personal and social adjustments.

This Changing World is the second book of this series. Like the first book, this one is organized into relatively few teaching units, which are divided into conveniently arranged chapters. Each of these units develops understanding of some large feature of our changing environment that is definitely associated with human interest. The instructional material of the unit is brought together because it belongs together for the development of an understanding of the problems associated with the unit. Furthermore, the order in which the units are arranged in the book is such that the learner acquires, as he progresses, an increasingly enlarged understanding of the major theme of the book.

We live in a world of change. The earth revolves and rotates under the rays of the sun. There is a continuous change through the day and from day to day in the intensity of the radiant energy on every region of the earth. There is, therefore, a continous flow of energy from regions where there is more toward regions where there is less. Solar radiation causes the motions of wind and water, it supplies energy to living things, and it is the source from

which comes all the energy used in industry. The difference in intensity with which solar radiation falls upon the regions of the earth causes climatic zones and changing seasons. This flow of energy causes continuous change. Mountains are worn down and carried to the sea. Other mountains are built up. Changes in the surface cause climatic changes. Living things change as they become adapted to new physical conditions. Life itself is characterized by continuous change as energy and matter flow in a cycle from the nonliving to the living and back again into the nonliving form.

In the development of the theme of *This Changing World*, experiences that are challenging to the interests of children in the eighth grade have been abundantly used. This array of experiences gives to the learner an orientation within the field of the objectives of the units, and these together develop the theme of the book.

Experiences are presented and associated in a continuous development. There are no interruptions within the chapter by exercises or other forms of teaching devices. Reading the chapter gives to the pupil a composite picture of some situation that has in it rich potentialities for further study. The aids to learning at the end of each chapter guide the pupil to further learning through direct observation and experimentation.

Obviously the aim of instruction in science is more than understanding. It is understanding plus ability to attain further understanding through the use of scientific methods. Ability to use the scientific method may be expected to result from practice in the use of the scientific method, especially when applied within an interesting area. The influence of learning on the behavior of the learner is reflected in the attitudes which he develops. In the preparation of this book it has been assumed that wholesome attitudes will develop from rich intellectual experiences. These experiences are presented in such a way that the

young learner may acquire some appreciation of the spirit and method of scientific work. At the same time these rich experiences afford abundant opportunity for exercise of scientific methods of thinking.

Through the study of these units in science, pupils should gain in ability to do independent thinking in this large field. Success in thinking is conditioned upon a wealth of ideas and upon recognition by the learner of challenging problems. These units set up problem situations that, because of recognized interest and importance, really challenge boys and girls. The demands of a favorable learning situation have been met when such problems arise and when the learner may participate vicariously and directly in the experiences which develop the ideas for their solution.

In the preparation of the manuscript for this book the authors have received assistance from many sources. They are deeply indebted to their colleagues in Teachers College and New Rochelle and to experienced teachers who have been students in their courses. It is a pleasure to acknowledge especially the indebtedness to Mr. Arthur V. Linden of Teachers College for his constant and original work in bibliographical research and in adapting certain sections of materials for pupils' use, and to Mr. Herbert J. Arnold, formerly of the Lincoln School and now of New College, for invaluable assistance in developing outlines and for constructive criticism on many parts of the manuscript. The authors wish also to express appreciation for suggestions made by Professor Kirtley F. Mather of Harvard University, who has read the book in proof. The geological drawings were made by Dr. Erwin Raisz. Miss Grace Graham of Newtown High School, in New York City, and Mr. N. E. Bingham of the Lincoln School have read all the manuscript and have made many helpful suggestions. Mr. O. E. Underhill and Miss June M. Common have assisted in many ways.

Contents

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Unit II · How may Different Climates and Changing Weather Conditions be Explained?

Unit V · Where does the Energy of the World Come From?

Unit VI · What has Man learned about the Story of Life?

To the Readers of this Book

What would you expect to find in a book carrying the title *This Changing World*?

An old man who has lived in the same community for over eighty years recalls with vividness the replacing of the rough country roads with pavement and tells with glee how he used to fish in the waters of a near-by creek which is now lined with docks and so dirty that no respectable fish could possibly live there.

"The world has changed so rapidly," he once said, "that if it weren't for one thing I'd be dreadfully worried."

"What do you mean?"

"Well, in spite of all the changes, do you know that the real enduring part of the world hasn't changed at all? As I sit on the front porch I see the same old sun in the sky. Those mountains in the distance have met my sight day after day for over eighty years, and the river over there has been flowing as long as I can remember. It seems good to have the old earth which changes but little. You sorter have something to tie to."

"But really that's not so," we said. "There probably was a time when all those things you think are so enduring were never there at all."

We told our friend of mountains worn down, carried to the sea, and rising again; of warm misty swamps rich with vegetation in what is now Pennsylvania; of the ice age, when huge sheets of ice covered nearly half of the North American continent; and of men who lived in caves and under overhanging rocks. We took him to a museum of natural history and showed him the remains of birds and mammals the like of which are unknown today as living animals. We told him that, while there were no exact records, there was definite evidence that changes had been in progress on this earth through two thousand million years.

This story as we told it to our old friend appears in this book, *This Changing World*. If you go forward in

your study, you will learn of the forces that cause change and the kind of changes which they cause. It is because of these forces that the surface of the earth and the plants and animals on it are as they are today. As we learn to interpret the things around us and we learn how these things came to be, our happiness and satisfaction in life are increased.

This Changing World is the second in a series, or group, of three books. The title of the series is A Survey of Science. The first book is called *The World Around Us*. In it you will find a simple story of how plants and animals live in their physical environment. This second book tells about changes in the environment and the forces that cause them. The third book of the series is *Man's Control of his Environment*. It tells how man has learned to control, to some extent, the forces that cause change. Through the use of his intellect he has learned to use forces, like those that wear down mountains, to run machinery. He has learned to control some of the forces that affect the character of the soil, and he has used this knowledge to produce more wheat, corn, and cotton.

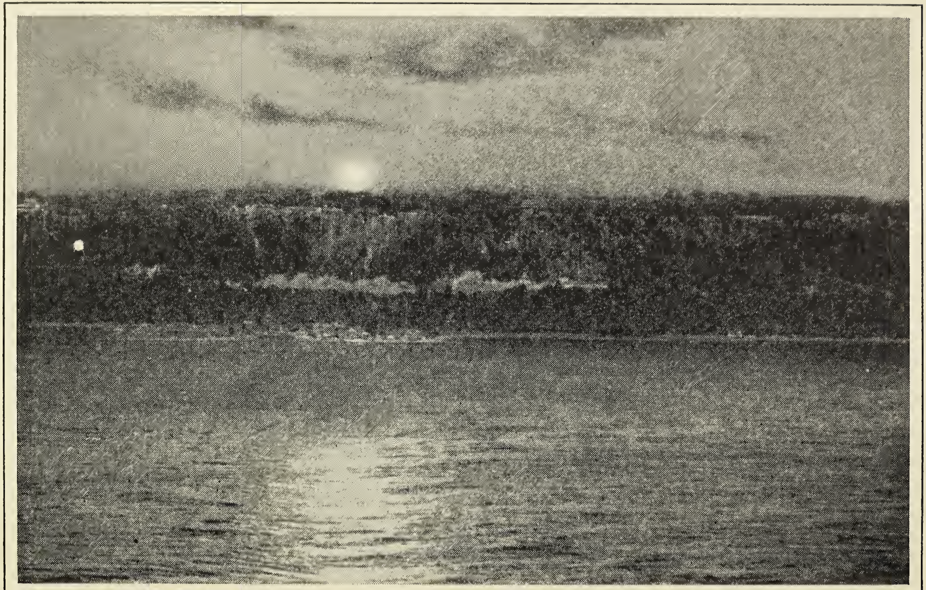
The wealth of the world is in the forces and in the materials which we may use. Through the study of science men have learned the vastness of the wealth on earth. There is more energy than we can use, more food than we can eat, and metals for every need.

In a world of abundance what are the limits placed on man's achievements? Through the use of his intellect he has built up the complex civilization of today. We may adapt ourselves to it through fuller understanding of ourselves and of the factors that produced the conditions in which we live. A Survey of Science shows something of the progress man has made in understanding the world around him, in understanding himself, and in gaining control of his environment. These accomplishments, which have come so rapidly, seem to suggest that far greater things lie ahead. Never before was there a time that offered so many interesting and important things to do. There are without doubt more important discoveries ahead than any that have been made.

THE AUTHORS

A SURVEY OF SCIENCE

BOOK TWO

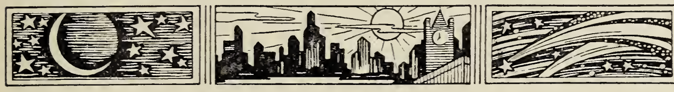


Ewing Galloway

FIG. 1. The Sun sinks beneath the Horizon as the Earth turns on its Axis

UNIT I

How may Certain Conditions on the Earth be explained by a Knowledge of the Solar System?



Chapter I · Why do the Sun and Other Stars seem to Rise in the East and Set in the West?

Chapter II · Why do the Planets change their Apparent Position among the Stars? What Other Members of the Solar System are There?

Chapter III · What Influence has the Sun upon the Physical Conditions found on the Various Planets?

Chapter IV · What are the Physical Conditions on the Surface of the Moon? What Effect has the Moon upon the Earth?

Chapter V · How do the Earth's Motions affect Conditions upon the Earth?

HAVE you ever walked through the silent countryside on a clear starlight night or stood upon a city roof top after dark? If you have, perhaps you too have felt the wonder of the ever changing picture above you. Night after night you may see the same moon, the same stars, and the same groups of stars, or constellations. Night after night they move onward, not in disorderly fashion but in an endless orderly procession, counting off the hours from darkness till dawn.

In the absence of earthly sights or sounds and with darkness all about you, the stars may seem very close. And yet you know that each of those countless points of light is an enormous round body. Each is a sun similar to our sun, possibly with planets revolving about it.

You wonder how scientists have come to know so much about these distant bodies: their size, their composition, their speed through the sky, and their distance from our own small earth. Do they mean anything, you ask, in the lives of people on earth—you and me, the people in the house across the street, the people in distant lands?

In this unit you may find information that will help you to answer some of your questions about the great universe in which we all live, and especially about our own solar system. Some of your questions cannot be entirely answered by anyone at the present time. Perhaps they never can be.

Chapter I · Why do the Sun and Other Stars seem to Rise in the East and Set in the West?

A. How do the Sun and Stars appear to Move?

Paralleling the eastern bank of the Hudson River and extending for almost the entire length of Manhattan Island is a wide parkway. Seeking a rest from the noise and the confusion of a great city, hundreds of people may be seen leisurely strolling along this drive in the late afternoon and early evening. Looking to the westward they see the broad expanse of the Hudson River, its waters, silvered by the rays of the sun, rippling in the faint evening breeze. On the western shore are the rocky cliffs called the Palisades. Here is a beautiful setting from which to observe the sunset.

The setting sun is a feature of the changing environment

Let us in imagination join the crowd on the drive and stroll slowly with them. The air is nearly clear. Yet there is enough haze to dull the sharp brightness of the sun's rays. Thus one may look directly at the sun without injury or discomfort to the eyes. It can be seen as an immense glowing ball apparently hanging just a few feet above the rocky cliff on the western shore of the river.

Only a brief observation is sufficient to convince you that the scene before you is changing. Each passing minute brings new beauties. You stop and face the west. Suddenly you realize that the other strollers have done the same. There you stand, all of you, like soldiers at attention, watching the gradually changing west. The top of the Palisades and the edge of the sun seem to be coming closer together. In a few minutes the lower edge of the sun is cut off as it slowly sinks behind the cliff. At first, just the lower rim is hidden, then half, then almost all, and finally it is completely hidden. Following the disappearance of

the sun, there is a brilliant glow in the western sky. In time this dims. The twilight fades, and finally the stars appear.

To people of today, as to people of old, the apparent motion of the sun — its rising, its passage across the sky, and its setting at evening — is a striking part of the changing environment. Have you ever wondered about these things? The stars too are a familiar feature of the changing environment. What do you know about the stars? Turn your eyes skyward at dusk on some clear evening. You see one star, then another, and then several more. Perhaps you begin to count them. At first there are but few, but as the darkness grows more intense, the number that may be seen increases so rapidly that you soon stop counting. If you have gazed into the sky on a clear winter evening when there was no moon, you know that wherever you look there are stars. Some are dim, others bright; some appear to be grouped in rather orderly fashion; others seem far apart, with no suggestion of arrangement.

The stars which rise in the east set in the west

If you were to fix your attention upon a particular star or group of stars, you would see that it, like the sun, seems to move westward. You may easily check this for yourself by making some observations of the heavens in September or October. Figure 2 is a star map of part of the northern heavens for the month of September. During these months you may see the bright star Vega in the early evening. If your home is near the fortieth parallel, Vega appears almost directly overhead. If you live in the northern United States, it is a little to the south of you. From points in the southern United States it is a little to the north. Vega is located in a constellation, or group of stars, called Lyra, or the lyre. It may easily be located in the sky, for there is no other bright star near it.

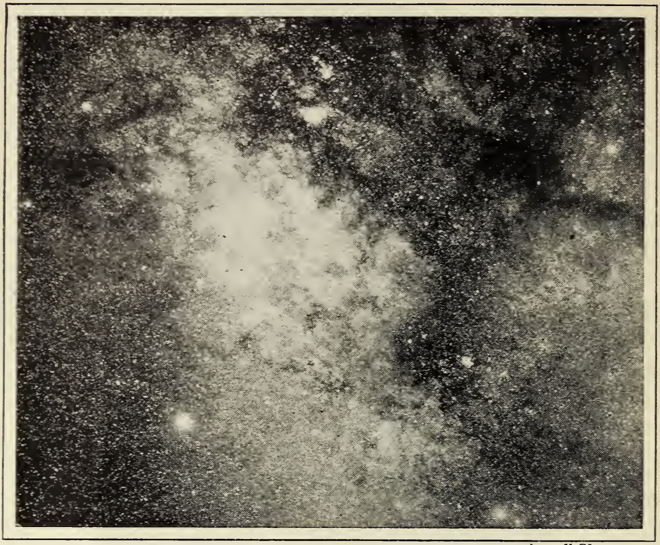
After you locate Vega, turn your eyes to some other parts of the sky. Halfway up the eastern sky, a little to

FIG. 2. A Star Map for 8 P.M. at about the Middle of September (Latitude 40° North)

The observer is facing the northern sky. (Courtesy of *The Monthly Evening Sky Map*)

the north of east, is the square of Pegasus. West of Lyra and a little to the north is the constellation Boötes, and in this constellation you will find the bright star Arcturus. If there is no moon and you are away from bright lights, it will be easy to see the Milky Way as a great bank of light across the sky. Note the countless stars, small and large, bright and dim, pictured in Fig. 3. This is a photograph of a section of the Milky Way taken through a telescope.

After you have fixed the location of some of these stars in your memory, go indoors for several hours. When you come out again, you will find that the scene has changed



Lowell Observatory

FIG. 3. The Milky Way is composed of Countless Stars

How many stars do you think are pictured in this photograph of a small section of the Milky Way?

and that the stars you saw before are not in the same position in the sky.

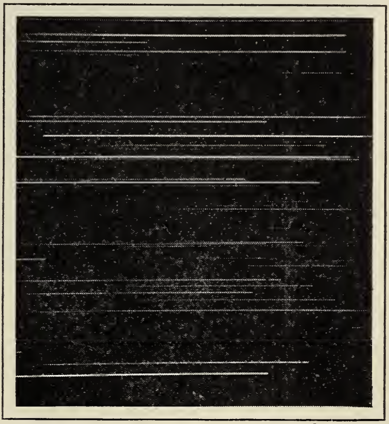
The position of the stars seems to change as time passes

Within three hours Arcturus seems to have moved to the western horizon; Vega seems to have moved halfway through the distance between overhead and the western horizon; Pegasus is overhead; and new stars, including the dim cluster known as the Pleiades, have come into view in the northeast. A few hours later Vega will have passed beneath the horizon in the northwest and Pegasus may be seen in the west. Time passes. The stars of the western sky continue to set as other stars rise in the east.

Thus the stars seem to move across the sky in a regular procession, keeping all the time the same relative positions

with respect to one another. They do not get closer together, nor do they get farther apart. The stars that seem to pass directly overhead rise in the northeast and set in the northwest. Those that rise in the east seem to pass south of directly overhead and set in the west.

The change in the scene as you gaze toward the stars goes on slowly. Watching the change is a little like watching the hands of a clock. It is so slow that you may not be conscious of it. A camera, however, will furnish more convincing evidence that the change is taking place. On a clear night when there is no moon, mount a camera so that it points toward the east. Open the shutter wide and leave it for a period of, say, two hours. Then close the shutter, remove the film, and develop it.



Yerkes Observatory

Fig. 4. These Star Trails were photographed at the Equator

How would a photograph of star trails taken from where you live be different from this one?

If your picture is a successful one, it will be like the one shown in Fig. 4. The white lines on the films are pictures of the stars. But why are they lines? you may ask. There seems to be only one answer to your question. The apparent positions of the stars have changed. Besides, since all the lines in your picture are of the same length and since all extend in the same direction, you come to the conclusion that all the stars appear to have moved the same distance and in the same direction. Are the lines on your film straight or slightly curved? Why?

Your observations up to this point have been of stars in the eastern and western sky. Turn your attention now to the northern sky. Find the Big Dipper. This constellation with its seven stars is the most prominent group in this part of the sky. Two stars of the Dipper are in line with the North Star (or Polaris) and are called the Pointers. You probably know why, but in case you are in doubt look at Fig. 5.

In the north the stars appear to move around the polestar

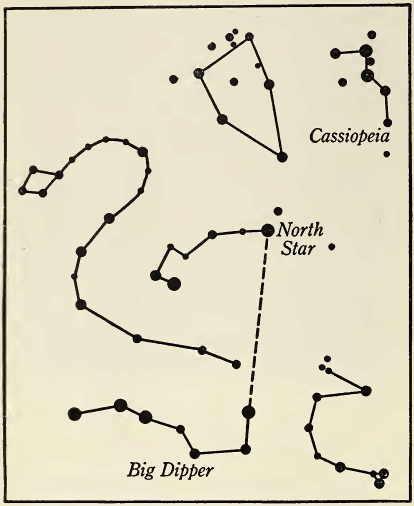


Fig. 5. Two Stars of the Dipper are in Line with the North Star, or Polaris, and are called the Pointers

Based on a portion of a map in *A Beginner's Star-Book*, by Kelvin McKready, published by G. P. Putnam's Sons

Give particular attention to the North Star. Of all the stars in the sky this is the only one whose position does not seem to change. Every hour through the night and every night through the year it seems to remain in the same place. Another constellation easily seen in the northern sky is Cassiopeia. Its apparent distance from the North Star is about the same as that of the Big Dipper, but in the opposite direction.

Do these stars in the northern sky also move? If you were to point your camera toward the North Star and take a picture as you did a short time ago, you would find that they do move. Your picture would look like the one in Fig. 6. Compare Fig. 6 with Fig. 4. Do you see any differences? Notice that in Fig. 6 the stars seem to move

Lowell Observatory

FIG. 6. The Trails of Some Stars seem to be Circular

Why should these trails differ from those in Fig. 4? The arrow points to the trail of Polaris, the North Star

in a circle. Complete circles would be formed if you could leave a film exposed for twenty-four hours. The portion of a very small circle near the center of the picture is the trail of the North Star. Thus there is evidence that the North star, like the others, seems to move along a circular path. But the circle is very tiny, and in ordinary observation the position of this star does not seem to change at all.

Why should the stars that you see in one part of the sky seem to rise and set, while others are always visible? All of them seem to move in circles. But those that rise in the east set in the west, for part of the circle along which they seem to move is beneath the horizon. The stars of the north do not rise and set, for the circumference of the circles along which they seem to move is always above the horizon. A study of Fig. 7 may help to make this clearer.

Now you have made a number of observations. Let us summarize them:

1. The sun and some of the stars rise and set.
2. From day to day and from year to year the stars maintain the same relative positions with respect to each other.
3. Stars in the north seem to move in circles around the North Star.
4. Stars that pass directly overhead rise in the northeast and set in the northwest. Stars that rise directly in the east pass south of overhead as they swing across the sky, and set directly in the west.

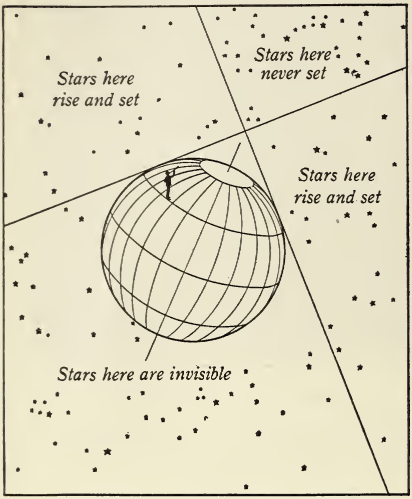


Fig. 7. Why are Some Stars always Visible while Others seem to Rise and Set?

Can you explain these observations? Why do the stars seem to move? Why do the stars of the north seem to move in circles around the North Star? Why does the sun seem to rise in the east and set in the west?

B. Do the Sun and Stars really Move?

If you are to answer the questions we have just raised, it will be necessary to use your imagination and build up an explanation of the things you have seen. Such an explanation will be the best guess you can make. Such a guess may be called a hypothesis. The hypothesis should be tested to see whether or not it explains the observations that have been made. If it does explain them, it may be

accepted as a theory. It is quite possible that several guesses will have to be made and tested out before a really satisfactory explanation is found. Let us see.

It may seem that the simplest explanation of your observations is to say that the earth is stationary in space and that the sun and the stars move about it. In ancient times people thought this was the case. But as man learned more about these heavenly bodies, he found that this apparently simple explanation is not satisfactory. Why not?

For one reason, it is now known that the sun is a very great distance from the earth. If the sun moved around the earth, it would move along a circle the radius of which is the distance of the sun from the earth. This distance is about 93,000,000 miles. If the sun moved in a circle around the earth, the diameter of this circle must be 186,000,000 miles and the circumference would be nearly 600,000,000 miles ($3\frac{1}{7} \times 186{,}000{,}000 = 584{,}571{,}428$). If the sun moved around the earth, it would move through this great distance in twenty-four hours. This would be at a speed of nearly 7000 miles in one second. When we apply this theory to the apparent motion of the stars, we find it still less satisfactory as an explanation of what we see. The nearest of the bright stars (Alpha Centauri) is 270,000 times farther away than the sun.

The stars are very far away

This *nearest* star would have to move at a speed of nearly 2,000,000 miles per second if it were to make one complete circle about the earth in one day. Other stars are very much farther away than this nearest one.

The simplest explanation, then, that the sun and the stars move around the earth, seems entirely unsatisfactory, for it seems unreasonable to think that the sun and the stars are moving so fast. There are, in fact, other good reasons why astronomers think the stars do not move around the earth. Accordingly this explanation must be given up. Let us try another.

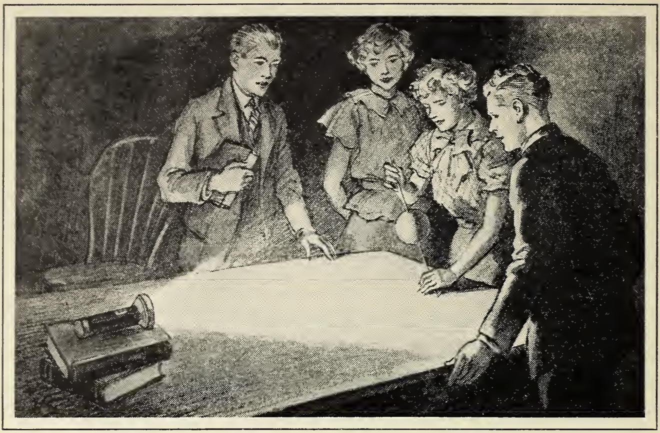


Fig. 8. To a Tiny Observer on the Orange the Flashlight would seem to Rise and Set as the Orange turned

Suppose that the earth moves, and that the sun and stars are stationary. State the supposition in this manner:

The motions of the earth make the stars seem to move

(1) The earth is a large, nearly round object, (2) it turns on an axis, (3) the direction in which it turns is from west to east, and (4) the stars do not move. In order that you may have a clearer understanding of this hypothesis, run a long needle through an orange, as shown in Fig. 8. Support the orange by holding the two ends of the needle, and rotate it so that its surface moves from west to east. Can you imagine a tiny observer on the orange? As the orange turned, it would seem to him as if the objects round about were moving along a circular path in much the same way that the stars seem to us to move around the earth. To this tiny observer the orange would seem to be stationary, just as the earth on which we are located seems to us to be stationary.

We have supposed now that the earth rotates and that the stars are stationary. Let us see if this hypothesis is

enough to explain what we see as we gaze into the sky. Think of the axis on which the earth turns as an imaginary line through the center of the earth. It is similar to the long needle through the orange. The points on the surface of the earth through which this line passes are called the north pole and the south pole. This line extended out into space passes near the North Star. In other words, the south pole, the north pole, and the North Star are in almost the same straight line. Now if the earth turns on this axis, it must turn from west to east, for stars (and the sun) in the west soon pass out of view. Similarly stars in the east seem to rise higher in the sky. According to our hypothesis, then, we stand on a huge ball which rotates, or turns, from west to east. As we are carried along, the scenes in the sky are continually changing.

The earth turns from west to east on an axis

Is this hypothesis a reasonable one? The diameter of the earth is known to be about 8000 miles. Its circumference is therefore about 25,000 miles. Objects on the earth at a position halfway between the poles, that is, at the equator, move in twenty-four hours through a distance equal to the circumference of the earth at the equator. This is at the rate of about 1000 miles each hour (25,000 $\div$ 24 = 1041). Even this is fast, but airplanes have flown at a speed almost half this. Such a speed of rotation seems possible, doesn't it?

Now come back again to your observation of the stars. People who live along the line which passes through Bangor (Maine), Minneapolis (Minnesota), and Salem (Oregon) are on a line just about halfway between the equator and the north pole. If one were to move north from this line, that is, toward the north pole, the North Star would be higher and higher in the sky, until at the north pole it would be directly overhead. On the other hand, if one were to move south, the North Star would be

The observation of the stars furnishes evidence that the earth is a sphere

nearer and nearer the horizon, and at the equator it would be just barely visible on the horizon. This is one bit of evidence that the earth is a sphere. Do you see why?

At the poles none of the stars rise and set

At the north pole itself there would be no rising and setting of stars. At a position a little to the south, stars near the horizon would not be visible all the time; for, as you have seen, a part of the circles along which they seem to travel would lie beneath the horizon. These stars would rise far to the northeast and set in the northwest. If one moved farther south, still larger sections of the northern sky would rise and set, until from the equator all stars would rise and set. At that point the stars rising directly east pass directly overhead and set directly west.

At the south pole the observations would be like those at the north pole. All the stars would seem to move about the observer in circles. In a position north of the south pole the stars that seem to pass overhead would rise in the southeast and set in the southwest. In a region that is as far from the south pole as we in the United States are from the north pole, the observations of the stars would be about the same as ours in the United States. However the stars (and the sun) would seem to swing northward as they rose from the east and would seem to swing toward the southwest as they moved toward the horizon.

Paths which stars seem to follow depend upon the position of observer

All these observations of the apparent motion of the stars may be explained if you will suppose that the earth is a sphere and that it turns on an axis. The stars that you see and the paths that they seem to follow depend upon your position on the surface of the earth. At the north pole the stars seem to move around in circles. According to our theory this is really because the earth is turning, for the real position of the stars does not change.

To state the same suppositions in another way: You are in space on a big round ball that is rapidly spinning round

and round. This round ball (the earth) makes one complete turn on its axis once in twenty-four hours. The stars are out in space, and their real positions with respect to each other remain so nearly the same from year to year and from century to century that we may for practical purposes suppose that they do not move at all. On the earth, *straight up* is the direction away from the earth. What you see as you look straight up changes continually, for the earth is turning on an axis and you are riding along on its surface. As the earth turns from west to east, the stars seem to move from east to west. What seems to be the movement of the stars is really not movement at all. The real motion is the motion of the earth. It turns on an axis; and as you ride along on its surface, stars come into view over the eastern horizon and pass out of view beneath the western horizon.

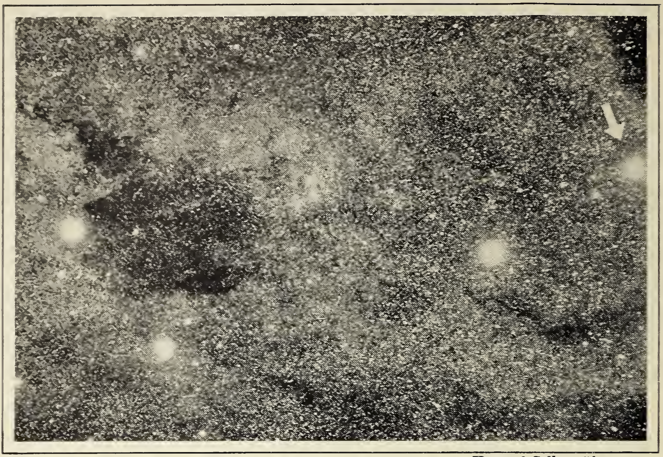
The position of the stars seems to change because the earth moves

In the same manner you may explain the rising and setting of the sun. Day after day the sun seems to pass across the sky. The supposition that the earth turns on an axis furnishes the explanation of the rising and setting of the sun.

So far as daily observations are concerned, then, the sun and the stars do not move across the heavens. These apparent motions are due to the earth's rotation. But it would be wrong to say that they do not move at all, for observations with accurate instruments seem to show that the sun and all the other stars are moving through space.

They are so far away, however, that these motions cannot be detected except by most careful observations. The nearest bright star is Alpha Centauri, "the brightest star in the constellation of the Centaur." It is shown with other stars in Fig. 9. This nearest star (visible within the Southern Hemisphere) is about twenty-five million million miles away. Astronomers have evidence that it is moving away from the earth at a speed of about ten miles per second.

Stars seem to be stationary, but they really move through space



Harvard College Observatory

Fig. 9. The Nearest Bright Star is Alpha Centauri

Photograph taken through a telescope

The brightest of all stars, as seen from the earth, is Sirius. It is the nearest one that can be seen from the Northern Hemisphere. Can you find it in Fig. 10? It is twice as far away as Alpha Centauri. Vega is one and one-half million times as far from the earth as the sun is, and many of the stars are even farther away than this.

At these great distances the change in position of stars during all the period of recorded history can hardly be observed. The Indians who roamed the plains of America a thousand or five thousand years ago saw and named the same constellations which you may see tonight. Star charts made by the ancient Greeks more than two thousand years ago are nearly as accurate for use today as they were when they were made. From our own ordinary observations we should surely say that the stars do not move.

Through a long period of time there is no apparent change in the relative positions of the stars

The supposition, then, that the earth rotates once a day

Lowell Observatory

FIG. 10. Of All the Stars, Sirius is Second to the Sun in Brightness

Photograph taken through a telescope

furnishes a satisfactory explanation of all your observations on the sky. In addition, no observation has ever been made that may be used as evidence that the earth does not rotate. Therefore this theory is a good one, and it will be accepted as a true explanation of the observations made unless at some time someone gathers observations to prove that it is not true. This is extremely unlikely.

The earth turns on an axis once a day, moving from west to east. This rotation makes the heavenly bodies *seem* to move across the sky from east to west.

Can You Answer these Questions?

1. Is it correct to say that the stars do not move? Defend your answer.

2. What is the difference between a hypothesis and a theory?

3. Why does it seem unreasonable to believe that the sun and the stars move around the earth?

4. Why does it seem reasonable to believe that the earth moves around the sun?

5. Can you see the North Star from a point on the equator? from a point south of the equator? from the south pole? Explain your answers.

6. Why do the sun and the stars seem to move from east to west rather than from west to east?

7. Can the Big Dipper be seen at any time of the year by people who live in Argentina?

8. Since the earth is moving about the sun, why is it that the stars seem always to be in the same relative position?

9. Why are the stars of the northern sky always visible while others rise and set?

10. What proof have you that the stars do not seem to change their relative positions?

11. Suppose that you were standing at the north pole in winter. How would the stars appear to move?

Questions for Discussion

1. When you look at the sun overhead at midday, you cannot see that it is moving. At sunset, however, you see a change from one minute to the next. Why is this?

2. Why do you think it was easier for the ancients to believe that the sun and other stars revolved around the earth than to believe that the sun was the center of the solar system?

3. Sometimes you see the Big Dipper right side up; at other times you see it upside down. How can this be?

Here are Some Things You May Want to Do

1. Ancient people explained many things about the heavens by means of stories and myths. You may wish to read some of these. Try Williamson's *The Stars through Magic Casements,* Gayley's *Classic Myths,* or Johnson's *The Star People.*

2. Many of the stars seem to have peculiar names. Look up some of them, such as Arcturus, Aldebaran, Sirius, and Pollux, and see if you can find why these names were given to them.

3. Study star maps for the different months of the year. What changes do you find from month to month? Give a class lecture on "How to find the Stars All the Year Round."

4. Take some pictures of the northern sky when there is no moonlight, using a time exposure. Does your film look like that in Fig. 6?

5. See if you can find out how the astronomers have determined the distance of the stars from the earth.

6. There are many great observatories in the world. Among them are Mount Wilson, Lick, and Yerkes. See if you can find any description of them and the work they are doing. Prepare a class report on this.

Chapter II · Why do the Planets change their Apparent Position among the Stars? What Other Members of the Solar System are There?

A. What are the Motions of the Planets?

The planets look to the naked eye much like the stars except that some of them are considerably brighter. There is one striking difference between the planets and the stars. The planets move. The word *planet* means "wanderer." These bodies seem to wander across the sky. In addition, the steadiness of their light sets them apart from the twinkling stars.

Planets are not stars

If you should observe the heavens night after night, year in and year out, you too would grow familiar with these wanderers, or planets, as the Greeks named them. Like other careful observers in the past you would become aware of the fact that the planets change their positions with respect to the stars. You would learn always to look for them along a certain path in the sky; you would find that all of them follow very closely the route of the sun and the moon. After certain definite periods of time you would discover that they return to the same positions in which you first saw them.

The brightest of the planets is Venus. It is also nearest to the earth. Sometimes you may see it as a bright "evening star" and at other times (if you are up before sunrise) as a bright "morning star." After observing Venus for a few evenings you see that it is moving. It changes its position in the sky, not only in relation to the stars but also in relation to the sun and to the other planets.

Venus always appears fairly near the sun, but is not so close as Mercury. Neither of these is ever seen in the middle of the night. You will find out why very shortly. Three other planets, Mars, Jupiter, and Saturn, are also bright

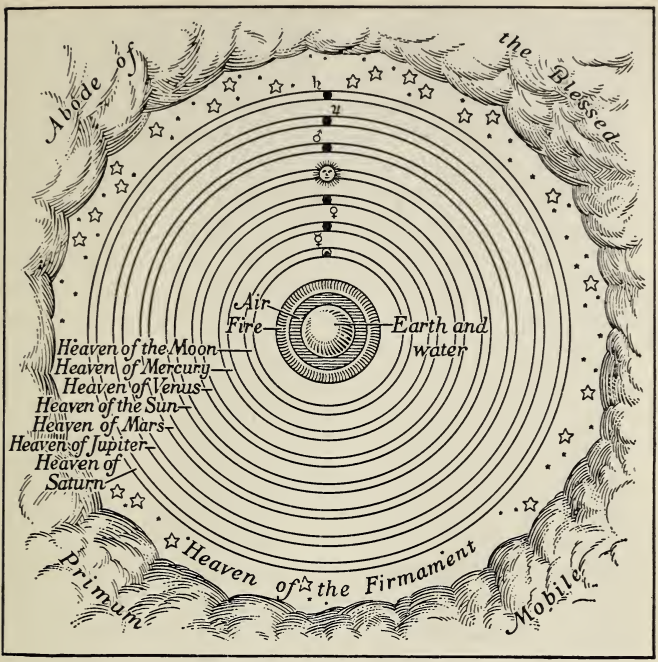


Fig. 11. Ancient Peoples believed that the Earth was the Center of the Solar System

How many differences can you find between this idea of the solar system and the one in Fig. 12?

objects among the stars. These planets, like Venus, rise, move across the sky, and set as the sun does; and their positions with respect to the stars change slowly.

How do the motions of planets differ from those of the stars? In explaining the reason why planets seem to wander, early scientists got themselves into great difficulty. Most of them believed, as you will recall, that the earth was at the center of the universe and that the sun, moon, and stars went around it. In Fig. 11 the artist has copied an old drawing showing the solar system according to

ancient beliefs. You have learned that you can explain the apparent motion of the stars if you suppose that the earth turns. This same supposition and some others must be made in order to explain the motion of the planets.

Late in the fifteenth century, shortly before Columbus discovered America, a Polish astronomer named Copernicus hit upon an idea that simplified matters. It was not entirely a new idea, for at least one Greek scientist had considered it nearly two thousand years before. But it had long since been forgotten. The explanation suggested by Copernicus seems to be very close to the truth. He took it for granted that the planets, including the earth, *move around the sun* in circular paths and that the paths are all in about the same plane.

Copernicus suggested that the planets revolve about the sun

The paths, or orbits, of the planets, according to the modern theory, which is based upon the Copernican theory, are shown in Fig. 12. The sun, you will observe, is nearly at the center. In this figure you may see that Mercury is nearest the sun. This planet is so close to the sun that it cannot be seen except for a short time after sunset or for a short time before sunrise. It requires close observation to see it at all. Copernicus had never seen Mercury, but he explained that Mercury could be seen in the morning when it happened to be west of the sun at sunrise and that it could be seen in the evening when it happened to be east of the sun at sunset. Mercury makes one complete journey about the sun (one revolution) in eighty-eight days. There is therefore one interval in every eighty-eight days during which Mercury may be seen by close observation as an "evening star" and one interval during which it may be seen as a "morning star." Do you understand why this is so?

Mercury is closest to the sun

The next orbit about the sun is the path of Venus. We have already observed that Venus is at times a bright "evening star" and at other times a bright "morning

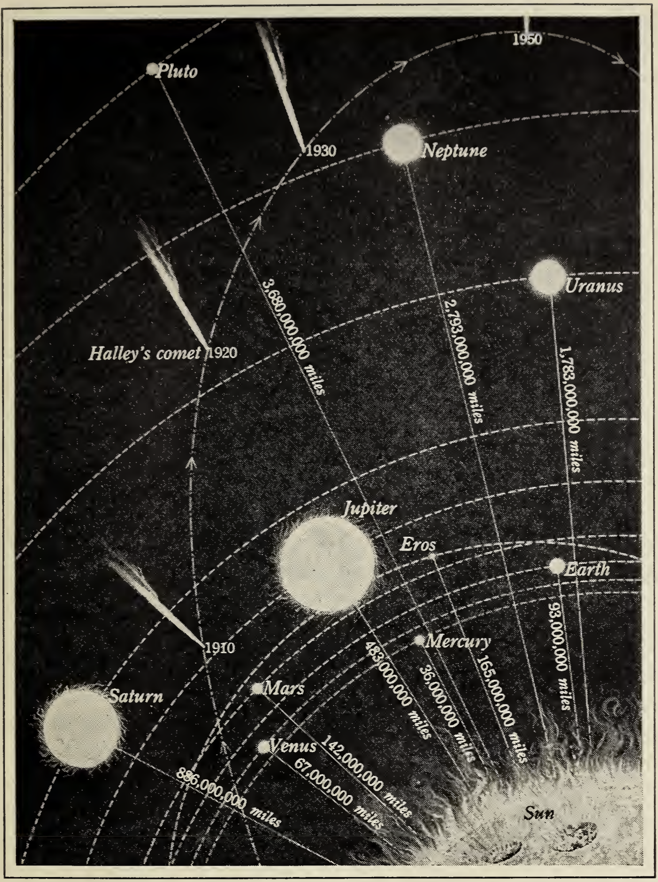


FIG. 12. The Modern Theory of the Solar System supposes that the Sun is at the Center and that the Planets revolve around the Sun

In addition to the sun, this diagram (which is based upon the Copernican theory) shows parts of the orbits of the planets, one of the planetoids, and Halley's comet. Notice that the comet is shown in four positions to indicate where it was in 1910, 1920, and 1930, and where it will be in 1950. Because of the limited space, the relative size of the planets is not accurate. Neither does the distance between the various orbits represent accurately the figures shown

star." Venus is visible in its highest position in the western sky of the early evening in May, 1935, and January, 1937. It may be seen in this position about every nineteen months after each of the dates. If you could take observations of Venus at the same time each evening, say at eight o'clock, soon after it first appears as an "evening star," it would seem for a time to mount higher in the western sky from night to night. Then it would seem to go lower until finally, after several weeks, it would be on the horizon at that hour. The planet appears to be trailing the sun, part of the time lagging more and more behind and again appearing to catch up the distance lost. Finally it seems to overtake the sun. Then you cannot see it. A little later it sets ahead of the sun. At this time it also rises ahead of the sun and may then be seen as a "morning star," brilliant in the sky until the rising sun blots out its glory.

According to the theory of Copernicus the third orbit about the sun is the path of the earth. The earth moves once around this path in one year.

You may now begin to see why it is difficult to understand the movement of the planets. First, you are on a planet which is turning on an axis. This causes all the objects of the sky except those directly in line with the north pole and the south pole to seem to move in circles. Second, this planet on which you live is moving in a path around the sun. If all the other planets were stationary, they would seem to move because the earth is moving, just as telegraph poles seem to move as you speed past them on a train. Third, all the other planets are also moving around the sun, and no two of them complete their paths around the sun in the same period of time. Thus there are times when Venus and the earth are on the same side of the sun and in the same straight line. At this time Venus is nearest to the earth, a distance of about thirty-six million miles. At another time the earth will be

Mercury and Venus are inside the orbit of the earth

FIG. 13. NICOLAUS COPERNICUS, *who proved that the Earth was not the Center of Things (1473–1543)*

FOUR and a half centuries ago, when Nicolaus Copernicus was a boy in Poland, many of the more promising youths were sent down into Italy to college, for at that time Italy was the center of learning of all Europe. Nicolaus studied astronomy at half a dozen universities. Several Greek and Roman thinkers had guessed that the sun was larger than the earth and that it, rather than the earth, was at the center of the solar system. But none of these men had been able to prove it, and their theories had long since been forgotten. Young Copernicus, who was good at mathematics as well as astronomy, at last proved, using mathematical equations, that each and every one of the planets revolves about the sun and that the sun is many times larger than all the planets put together. For years he worked to prove his figures and to check over all the equations he had used. Then for a long time he waited, working on explanations, because he wanted people to believe him when he wrote the story of his discovery. Finally, just before he died, his book was published. It was called *De Revolutionibus Orbium Coelestium*, which is Latin for "*Concerning the Revolutions of the Heavenly Bodies.*" In spite of his clear mathematical proofs, however, it has been only within the last hundred years that the most stubborn of his opponents have been won over. How people did hate to believe that our little earth was so small and unimportant!

E. C. Slipher, Lowell Observatory

Fig. 14. The Planet Venus, when observed through a Telescope, shows Phases

Locate each of the phases shown on the diagram in Fig. 15

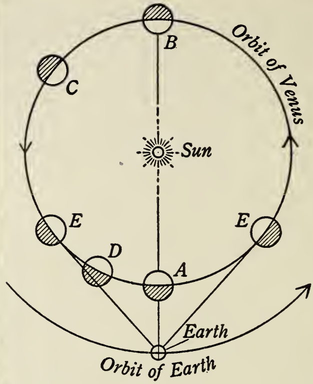


Fig. 15. Why is Venus sometimes seen in Crescent Form? There is a Cycle of Changes in the Appearance of Venus as it moves in its Orbit[1]

on the opposite side from the sun, with Venus, the sun, and the earth again in a straight line. At this time Venus is at its greatest distance from the earth, some one hundred and sixty million miles.

Venus and Mercury are nearer to the sun than the earth is. Both these planets, when observed through a telescope, appear at times crescent-shaped and at other times round. As you can see from Fig. 14, they pass through phases, or regular successions of change, just as the moon does. Through a telescope they appear crescent-shaped when they are on the side of the sun that is nearest the earth, for at this time we can see from the earth only a small part of their lighted surfaces. These planets appear round like the full moon when they are on the side of the sun opposite from the earth, for in this position the fully lighted surfaces are visible. This is explained more clearly in Fig. 15.

[1] Redrawn from Baker's *Astronomy*. D. Van Nostrand Company, Inc.

When Venus is in line with the sun as shown in position *B*, the fully lighted surface of the planet is turned toward the earth. In position *A* the darkened surface is turned toward the earth. In positions *C*, *D*, and *E* part of the planet's surface is lighted and can be seen from the earth. Here is evidence that the sun and not the earth is at the center of the solar system. When Copernicus suggested the theory that all the planets revolve around the sun, he recognized that if his theory was true these planets must show phases. There were no telescopes at that time, and with the naked eye it was impossible to observe anything that would indicate that there was at one time a "crescent Venus" and at another time a round Venus. When Galileo, however, nearly a hundred years after Copernicus, turned his newly invented telescope on the skies, one of the first things he saw was the crescent of Venus as shown in Fig. 14. Venus appears to be much larger when near the earth than when farthest away.

The phases of Mercury and Venus furnish evidence which supports the modern theory of the solar system

Since the earth is the third planet in order of distance from the sun, all the others — Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto — move in orbits outside the orbit of the earth. Therefore they do not show crescent phases as Mercury and Venus do. When these six planets are visible at all, we see only the fully lighted surfaces. Since the orbit of each of these planets is outside the earth's orbit, there are times when the earth comes between the sun and each planet. There are times when these planets may be seen in the east soon after sunset, and there are times when they may be seen high overhead at midnight. Neither Mercury nor Venus can ever be seen in the east in the evening, overhead at midnight, or in the west in the morning. Can you show by diagram why Mars may at times be seen rising soon after sunset and why Venus can never be seen rising at this time?

The orbits of five planets lie outside the orbit of the earth

The fourth orbit about the sun is the path of Mars. The great path along which it moves is 283,000,000 miles in diameter. Mars completes one revolution in six hundred and eighty-six days. The distance from the earth to Mars is about 50,000,000 miles when these bodies are closest together. This is when the earth and Mars are in line with the sun and on the same side of it. When these planets are in line but on opposite sides of the sun the distance between these is about 230,000,000 miles.

Distances in the solar system are vast

Two other brilliant planets are Jupiter and Saturn. Jupiter moves in the orbit next outside the path of Mars. When it is on the same side of the sun with the earth and in the same straight line, its distance from the earth (a little less than 400,000,000 miles) is about four and one-half times as great as the distance of the sun from the earth. When it is on the opposite side of the sun from the earth and in the same straight line, its distance from the earth (about 575,000,000 miles) is about six times the distance of the sun from the earth. Nearly twelve years are required for Jupiter to complete one revolution. The path of Saturn is outside the path of Jupiter; and when Saturn is closest to the earth, it is nearly twice as far away as Jupiter is when Jupiter is nearest the earth. In appearance Saturn is about as bright as the brightest stars.

Outside of Saturn there are at least three more planets. These are Uranus, Neptune, and Pluto. Uranus may be seen by careful observers with the unaided eye. Neptune and Pluto are visible only with the aid of a telescope. There may be other planets beyond these, but they have not yet been discovered.

The theory of Copernicus builds up what seems to be a true picture of the motions of the planets, for if we accept it as true we can explain all our observations of the movements of the planets. It explains satisfactorily the fact that

the planets change positions with respect to the stars. The supposition that Mercury and Venus move in orbits that lie inside the path of the earth explains why Mercury and Venus can be seen only in the morning or in the evening. The supposition that the path of Mars is outside the path of the earth explains the fact that Mars may sometimes be seen at midnight, at other times in the morning, and at still other times in the evening. Since all observations of the motions of the planets may be explained by the Copernican theory, it is accepted as true.

The theory of Copernicus seems a satisfactory one

B. What is the Solar System?

The sun and the planets and other bodies that move about it make up the so-called solar system. It is called a system because it consists of one large central body about which all the others are moving. The dimensions of the solar system are very great. The circumferences of the orbits along which the planets move are so large that we can by direct observation trace the planets along only a small part of their paths. Pluto, the planet that is farthest from the sun, is about forty times farther from the sun than the earth is from the sun. This distance, though, is extremely small when compared to the nearest bright star. The nearest bright star (Alpha Centauri) is two hundred and seventy thousand times farther from the sun than the earth is from the sun. In space the solar system is very much by itself. If it were moving toward the nearest star at a speed of ten miles per second, it would not arrive at the star for about seventy-five thousand years.

In addition to the stars and the planets the one other body easily seen in the sky is the moon. The distance from the earth to the moon is about two hundred and thirty-eight thousand miles. The moon is therefore much closer to us than either the stars or the planets. The dis-

tance to the moon is equal to only ten times the distance around the earth. There are many automobiles and trucks that have been driven more miles than the distance from the earth to the moon. The sun is nearly four hundred times farther away than the moon. When Venus is in its path closest to the earth, it is about a hundred and fifty times farther away than the moon.

The moon is much closer to us than either the stars or the planets

Some of the other planets also have moons, or satellites. Mars has two, but they are both quite tiny, only a few miles in diameter, and they revolve very rapidly. Jupiter has nine satellites, three of which are larger than the earth's moon and two as large as Mercury. Saturn also has nine or more moons, Uranus four, and Neptune at least one. None have been discovered about Pluto, nor do Mercury and Venus have attending satellites.

Other planets have moons

You are building up in your imagination a picture of the solar system. You have seen the sun at the center with nine planets moving about it and with moons moving about the planets. You have seen Mercury speeding around the sun in three months. You have seen the more leisurely journey of brilliant Venus, which requires over seven months. You have seen the earth, with a comparatively large moon traveling once around it each month. You have seen Mars, somewhat smaller than the earth, with its two small companions; the giant Jupiter, with its large family of satellites; then Saturn, Uranus, Neptune, and Pluto, all following regular paths about the glowing ball at the center. The sun is much larger than the planets. If all the planets and all their satellites could by some interruption of natural forces fall out of their paths and crash into the sun, it would appear not noticeably larger than it does today.

But there are other members of the solar system. Though less easy to see, they are extremely interesting.

C. What is a Comet?

The comets were always looked upon by the ancients with wonder and reverence. Across the known heavens would come an unknown visitor, gleaming in its brightness and carrying a streaming tail of light. For a few months this visitor would move across the sky, and finally disappear. No one knew where it came from nor where it went. No wonder that these strange callers were looked upon as the warnings of angry gods, threatening ill to mankind. As time went on, however, astronomers studied these visitors as they did the other members of the solar system and found evidence that comets also traveled in regular orbits.

Lowell Observatory

FIG. 16. This Photograph of Halley's Comet was taken in 1910

The picture was of course made with the aid of a telescope. To the naked eye, the comet would not appear as brilliant as this

Most of you who read this book have probably never seen a comet; but in 1910, when your fathers and mothers were boys and girls, the famous Halley's comet was a very brilliant object in the night sky. In Fig. 16 is a photograph of this comet. It looked something like an immense skyrocket caught in

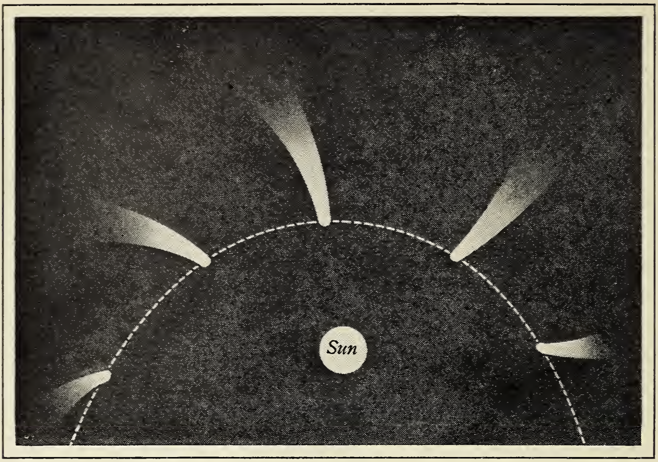


FIG. 17. The Tail of a Comet always points away from the Sun

the heavens as it moved toward the sun, with a streaming, fiery tail behind it. In the course of a few weeks it came out of space, moved in a long ellipse, or almost oval path, around the sun, and turned back to disappear again beyond the farthest planets. As it moved away, its fiery tail streamed in *front* of it. As it came and as it left, the tail pointed away from the sun. Notice Fig. 17. Because it was so far away, the comet seemed to be moving very slowly. Really, however, it moved along at a speed of several thousand miles an hour.

Comets travel in regular orbits

Halley's comet was visible for only a few weeks. This comet will reach its greatest distance from the earth in 1950, and after that it will turn back again toward the sun. How do we know this? As in the case of the planets, scientists can map the entire path of a comet if they know but a few points on its path, and they can tell how long it will take the comet to complete the journey.

Halley's comet appears regularly after a period of not quite seventy-six years. It is named after Halley, an Eng-

lish astronomer, who predicted its return. Halley, a friend of Sir Isaac Newton, saw the comet in 1682 and found by reading old records that it had been seen in 1607 and also in 1531. He predicted that it would appear again in 1758. His prediction came true, but Halley did not live to see it. The comet has since appeared in 1835 and in 1910. It will be inside the earth's orbit and visible again in 1985. Many of you will doubtless see it.

The appearance of comets may be accurately predicted

A comet, as you may have guessed, is quite unlike a planet. When a comet passes in front of a bright star, the star may be seen right through its head. It is believed therefore that the head of a comet is composed mostly of gases, with some solid pieces ranging in size up to that of huge rocks. The average density, that is, the weight of a unit volume, of the space in the head of a comet is probably less than one hundred-thousandth the density of air at the surface of the earth. The tail of a comet is even less dense. In 1910, although the earth passed through the tail of Halley's comet, no effect on the earth was observed, although some people thought that the sunsets were more beautiful than usual. Hundreds of comets have been seen with telescopes, but it is only on rare occasions that a comet large enough to be seen with the naked eye comes into the neighborhood of the sun.

The head of a comet is not a solid mass like a planet

Superstitious people are always terrified by the approach of a comet. A comet appeared during the conquest of England in 1066, and again during the war between the Mohammedans (Turks) and the Christians in 1456. At both these times all the people in the world were more or less terrified by the strange visitor. There is always someone who will predict the end of the world when a comet appears. Today educated people know that there is no relation between the appearance of a comet and happenings on the earth. Astronomers know that these objects move accord-

ing to the laws of gravitation. Comets may frighten ignorant people and they certainly furnish many problems of interest to scientists, but in other respects they exert no influence whatever upon human affairs. People are generally afraid of mysterious things. When the mystery is replaced by understanding, then observation of the object that once caused terror may bring to the observer a feeling of great satisfaction. All those who read this book would probably feel pleased if they could have an opportunity to follow the path of a comet as it moves night after night across the sky.

Knowledge overcomes fear and superstition

We are now coming to the end of our catalogue of the objects in the solar system. There is the sun with at least nine major planets moving in regular orbits around it. At least six of these nine planets have moons moving along with them. Then there are those strange visitors, the comets, that move in paths quite unlike the paths of the planets. In addition to these there are a great many objects, much smaller than the planets, called planetoids. Then there are still smaller objects called meteors.

D. What are Planetoids?

The planetoids are distributed in space between the orbits of Mars and Jupiter. The largest one that has been discovered is about five hundred miles in diameter. The smallest ones may be extremely tiny. More than a thousand have definitely been discovered, and there are without doubt many thousands of smaller ones. All of them revolve around the sun, but their orbits are not nearly so circular as are the orbits of the planets, as can be seen from the path of Eros in Fig. 12. They are called planetoids because they appear to be much like the planets, except that they are much smaller and their paths are more oval.

Planetoids revolve about the sun

E. What is a "Shooting Star"?

A "shooting star" is, of course, not a star at all. It is a meteor that has come within the atmosphere of the earth. As it travels through the atmosphere, it becomes very hot because of friction with the air. The small ones are quickly burned up because of the heat that is produced. They are changed into very fine bits of dust. These fine particles of dust slowly settle to the earth. Occasionally a large one passes through the air and falls on the ground. Those that reach the ground are called meteorites. Many large ones have been found and placed on exhibition in museums. The largest one in any museum is in the American Museum of Natural History in New York City. Its weight is about thirty-six and a half tons. It was found by Admiral Peary during one of his trips to Greenland and was brought by him to the museum, where it is now on display. The largest one ever found is estimated to weigh between fifty and seventy tons. It was found in Africa, and it still lies where it fell, as shown in Fig. 18. Many other evidences of meteorites have been found. Perhaps the most famous one in this country is at Meteor Crater in Arizona, a hole more than four thousand feet in diameter and over five hundred feet deep. A picture of this is shown in Fig. 19. According to the opinions of scientists this crater was caused by a tremendous meteor which at some time fell at this spot. It is thought likely that the meteor may have exploded when it struck the earth. Many small pieces of meteoric matter have been found in the neighborhood of the fall, but no large ones.

"Shooting stars" are meteors

Meteors frequently strike the earth

If you watch the sky for an hour on a starlight night, you may see possibly four or five meteors. It is likely that all of these will be small and will last as a bright streak for only a very short interval. The chances that you will be able to follow the fall of a meteor until it strikes the

W. J. Luyten, Harvard College Observatory

Fig. 18. The South African Meteorite is the Largest One ever Found

ground are very poor. In the whole world this observation is reported about four or five times in one year. It may seem that there are not many meteors, but really there are a great number. When you take observations on a clear night, you may see only those that appear within a circle not more than fifty miles in diameter. Therefore your observations may cover an area as great as two thousand square miles. Over every such area on the surface of the earth the average number of meteors that may fall each hour is possibly five or six. At this rate the total number entering the earth's atmosphere in twenty-four hours is nearly twenty million! The dust that is formed from these meteors as they burn is added to the earth and makes the earth larger. But it is increasing in size at a very slow rate. The total mass of the meteors that reach the earth in a million years is small when compared to the mass of the earth.

An enormous number of meteors enter the atmosphere every day

Very careful observers have found that meteors begin to glow in the atmosphere at an elevation higher than seventy-five miles. This observation is offered as evidence that the atmosphere extends out from the earth for more than seventy-five miles, for the meteor must have traveled for some distance through the air before it was hot enough to glow. Careful observations furnish evidence that the me-

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FIG. 19. Scientists believe that Meteor Crater, Arizona, was formed by a Falling Meteorite

teors move through the air at an average speed of about twenty-seven miles each second. If it were not for the fact that the atmosphere causes these things to burn and in burning to change to fine dust, the earth's surface would be bombarded every day by some twenty million pieces of stone and metal that would come shooting in at a speed of about twenty-seven miles per second.

There are different kinds of meteorites

The meteorites are the only members of the solar system besides the earth that we have opportunity to observe at close range. From this observation it has been found that there are three kinds of meteorites. One kind is composed of stony material somewhat like rocks found on earth. Another kind is composed of metal. The metal ones are mostly iron and nickel, with small quantities of other elements, including copper and cobalt. The third kind of meteorite is composed of a mixture of metal and stone. A chemical study of these meteorites shows that they are composed only of chemical elements that are well known on the earth. When you see one of these meteorites in a museum, you may want to ask where it came from. The only answer that can be made with certainty to your question is that it came from out of the sky. Many astronomers think that meteorites were at one time parts of comets. They think, too, that the comets

may have been at one time part of the sun. These pieces of stone and metal have most certainly traveled in space through enormous distances. If the story of their travels could be told, it would be most exciting.

The sun and the bodies that move about it make up a wonderful system. Remember that the sun is near the center of the system and that the other bodies move about it. The direction of motion of the planets about the sun is in the same direction as the rotation of the earth on its axis. Nearly all the satellites, or moons, move in the same direction.

F. What Forces hold the Bodies of the Solar System in their Courses?

You may wonder what keeps the planets moving or why they do not fly off into space away from the sun. They move in regular paths. For instance, the path of the earth is so regular that, as you know, we set our calendars by it. The position at which any of the planets will be many years hence may be predicted with very great accuracy. The answer to the question of why they do not stop moving is that there is nothing to stop them. There is no opposition to their motion through space, and so they move on and on. Some powerful force must have started these bodies moving around the sun, but once started, no other force is required to keep them going.

Why do they not fly off into space? You know that if you tie a weight to a string and swing the weight in a circle about your head, the weight pulls away from you. If the string breaks, the weight will fly away from you. The pull of the weight on the string as it swings around your head is called centrifugal force. All objects that move in circles, the earth and the planets included, exert a centrifugal force which acts as a pull away from the center of the circle around which they are moving. The planets do

In the solar system centrifugal force is balanced by gravitational force

not move farther away from the sun because there is another force attracting them toward the sun that is just equal to the centrifugal force that is pulling away. Perhaps Fig. 20 will help to make this clearer. This attracting force is the force of gravitation. It is the same kind of force as the one which attracts objects to the earth, causing them to fall.

All the objects of the solar system have more or less gravitational attraction for each other. Thus the earth and the other planets attract the sun, and the sun attracts the planets. The planets would be drawn toward the sun if they were not moving. The centrifugal force pulling away from the sun just balances the gravitational pull that would make them move toward the sun. The larger the bodies and the closer they are together the greater the force of gravitational attraction. The whole system is beautifully balanced. The system may seem like a perfect machine that never wears out nor gets out of order. It has been running for millions of years and will continue to run for millions of years more.

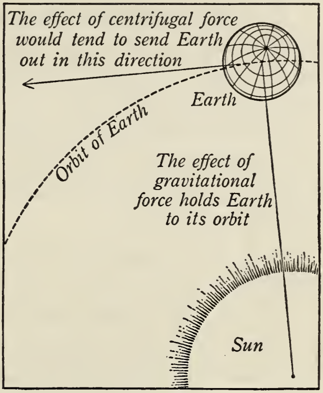


Fig. 20. The Centrifugal Force pulling Objects away from the Sun just balances the Gravitational Pull that would make them move toward the Sun

The sun is at the center of the solar system. The earth and the other planets revolve about it in nearly circular paths. Satellites revolve about most of the planets. Comets and planetoids move in almost oval paths, while meteors seem to be scattered throughout the solar system.

Can You Answer these Questions?

1. In what ways do planets differ from stars?

2. Why is it impossible to see the planets Venus and Mercury in the middle of the night?

3. What were the two main suppositions of the Copernican theory?

4. Venus completes one revolution around the sun in two hundred and twenty-five days. Why is it possible during this period to see the planet for a time as an "evening star" and for a time as a "morning star"?

5. Which are closer to the sun, the planets or the stars?

6. Which planet is nearest the sun? Which one is farthest from the sun? Can you name the planets in their order of distance from the sun?

7. What are some of the differences between a comet and a planet?

8. What is the difference between a meteor and a meteorite?

9. What are the distinguishing features of centrifugal force? What are the distinguishing features of gravity? What influences have these two forces upon the movement of bodies within the solar system?

10. What causes a meteor to burn as it passes through the sky?

11. What are the planetoids?

12. Both planets and comets move in orbits. What difference is there in the orbits of these bodies?

13. Why do Mercury and Venus pass through phases, or regular rounds of changes, just as the moon does?

14. Why do not the planets outside of the earth's orbit show all these phases?

15. How do the phases of Mercury and Venus support the Copernican theory?

Questions for Discussion

1. Sir Isaac Newton said, "If I have seen farther than other men, it is because I have stood on the shoulders of giants." What do you suppose he meant?

2. What is the difference between astrology and astronomy? Which is the scientific study? Why?

3. Is it possible for a comet to strike the earth? What do you think would happen if it did?

4. Can a person be an astronomer without being at the same time an expert in mathematics?

Here are Some Things You May Want to Do

1. Make a special study of some famous comets, such as Halley's, Encke's, Biela's, Morehouse's, or Donati's. You can get information from astronomy textbooks, encyclopedias, and perhaps from histories. Write a booklet giving a description of the comets — their appearance, composition, discovery, relation to the sun and the earth, and any other details which you think are interesting.

2. Copernicus was not the first man to believe that the sun was at the center of the solar system. Do you know who was? Would you like to find out? Read Henry Smith Williams's *The Great Astronomers.*

3. The following names are those of stars, planets, and constellations. Find out which are which:

Polaris	Vega	Taurus	Venus	Big Bear	Little Dipper
Pleiades	Sirius	Orion	Sun	Jupiter	Arcturus

4. Find out from some older people at home or in the neighborhood what they remember about the last visit of Halley's comet. Prepare a class report on what they tell you.

Chapter III · What Influence has the Sun upon the Physical Conditions found on the Various Planets?

As you read the description of the solar system in the last chapter, did any questions come to your mind regarding the various planets? Did you wonder, perhaps, whether they are at all like the earth?

Thousands of people over a long period of time have wondered about this. They have asked many questions. Is there water on any of these other planets? air? soil? Is there any life? Are there trees? animals? And, most interesting question of all, are there people living there?

A. What are the Conditions upon the Sun?

Did you ever visit a steel mill or an iron foundry? If so, you probably watched with excitement the flood of white-hot molten metal as it poured, bubbling and sizzling, from the furnace mouth into a waiting ladle. You may have wondered how hot this stream of metal really was. If you asked about it, you were told that it sometimes reaches a temperature as high as 2700° F.

Yet even this terrific heat does not begin to compare in intensity with the heat of the sun. That glowing ball which lights and heats the earth is so hot that the surface is believed to be entirely in the form of glowing gases. At certain times it is possible to see huge tongues of hot gas shooting out into space for hundreds of thousands of miles. These are illustrated in Fig. 21. At its surface the temperature of the sun is about 11,000° F., and the interior is certainly very much hotter.

The surface of the sun is composed of hot gases

Without doubt the sun is one of the most powerful of all the factors of our environment. Though ninety-three

million miles away and hidden from us half the time, its size is so great and its light and heat so intense that it controls conditions not only upon the earth but upon all the other members of the solar system. Its diameter is a hundred times that of the earth, and its volume a million times as large. The relative size of these two bodies and the other planets is illustrated in Fig. 22.

The sun is very much larger than the earth

Frederick Slocum, Yerkes Observatory

FIG. 21. The Tongues of Hot Gas which may sometimes be seen shooting out into Space from the Surface of the Sun give Evidence of Intense Heat

The quantity of matter in the sun — that is, its mass — is more than seven hundred times as great as that in all the other bodies of the solar system taken together. Its mass is more than three hundred and thirty-three thousand times the mass of the earth. The mass of Jupiter, the largest of the planets, is about three hundred and seventeen times that of the earth. The mass of the sun is therefore more than a thousand times as great as the mass of Jupiter.

At the temperature of the sun the chemical elements with which we are familiar as solids on the earth are in the form of gases. The atmosphere of the sun contains magnesium, iron, silicon, sodium, potassium, calcium, aluminum, and other substances. Of the elements in the sun's atmosphere that are

Iron and aluminum are gases on the sun

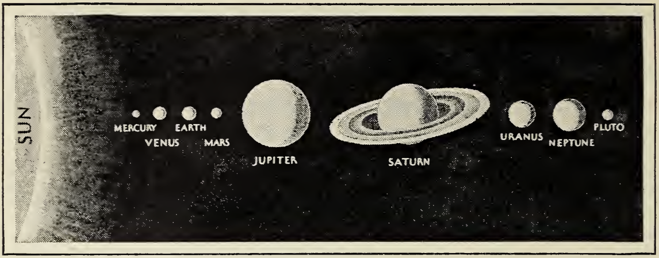


Fig. 22. The Diameter of the Sun is One Hundred Times that of the Earth

What is the relative size of the earth compared with the other planets?

known as gases on the earth, hydrogen, oxygen, and helium are the most abundant. In general the elements that are most common on the earth are also most common in the sun; but the lighter gases, hydrogen and helium, are much more abundant in the atmosphere of the sun than on the earth. The reason for this probably is that the earth is not large enough for its gravitational force to hold these lighter gases in large quantities.

No elements are known to exist on the sun that do not exist on the earth, although by study of the sun's light helium was discovered in the sun's atmosphere several years before it was found anywhere on the earth.

The surface of the sun has also been studied by the use of the telescope, and many photographs have been taken. Such observations have revealed a number of dark spots on its surface. These are the famous "sun spots," which come and go upon the sun, being very numerous at some times but scarce at other times. A single spot may be several thousand miles in diameter. In Fig. 23 is an illustration of such a spot photographed through a telescope.

There is an unexplained relationship between these sun spots and the weather of the earth. When there appear to be the most spots on the sun, there is likely to be an unusually large number of thunderstorms on the earth. At such

Mt. Wilson Observatory

FIG. 23. Large Spots Similar to these may sometimes be observed on the Sun

times static interferes with radio communication. Several noted astronomers of the present day are devoting their lives to a study of sun spots, in the hope that long-time weather predictions may be made from them. Some progress in this study has been made.

Sun spots affect the weather of the earth

There are of course many millions of square miles of hot surface on the sun. Radiant energy moves out from it into space in all directions. There is plenty of evidence of this energy. Think of energy as the source of forces that make things move. Human beings have energy, for they can move about. This energy comes from the foods they eat. The process of food-making goes on in green plants. In this process energy from the sun's rays is stored in foods. You have probably learned that energy from the sun causes the wind to blow and causes water to evaporate. Heat is a form of

All our energy comes from the sun

energy. Strictly speaking, the sun's rays are not heat. They represent, however, a form of energy that changes into heat when the rays strike the surface of the earth.

Some of the rays from the sun fall upon each of the planets. On all the planets, however, the energy of the rays is changed into heat just as on the earth.

The intensity of these rays varies with the distance of the planet from the sun. On Mercury, because it is closest to the sun, the heat is most intense. Where its surface is exposed to the sun, it is probably always hot enough to melt tin, or at least 446° F. On Pluto the temperature is very low, probably much lower than the temperature of liquid air, or − 318° F. On the earth, which is about three times as far from the sun as Mercury and about one fortieth as far away as Pluto, the conditions are temperate and favorable for life as we know it.

Only a small part of the energy of the sun reaches the earth

Of all the sun's rays an extremely small amount reaches the earth and the other planets. At their distance from the sun the planets are but mere points, and the vast region around is empty space. The rays pass through this space; and as the planets move in their courses, they are heated and lighted by them. The planets themselves are dark bodies. We can see them at night only because they are lighted by the rays of the sun.

It is difficult to explain the fact that the sun continues to give off heat without getting cooler. No satisfactory explanation of this fact has ever been made. There is, though, good evidence that the sun has been radiating energy into space at about the same rate for some billions of years, and there is no reason to think that it will not continue to radiate energy at about the same rate for more billions of years.

The importance of the sun, then, is obvious. Its rays furnish heat and light to the bodies of the solar system, and its gravitational pull holds the planets in their courses.

While it may seem entirely different, yet in many ways the sun is like the stars. Perhaps some likenesses would be revealed if the sun could be seen from some point outside the solar system. Let us see if we can draw such a picture for you.

The nearest bright star is Alpha Centauri. It is visible in the southern hemisphere and appears in the sky as an ordinary bright star. Its distance from the sun is some 270,000 times greater than the distance from the earth to the sun. What would it look like if it were only as far away from us as the sun? The answer is that it would be very much like the sun. It would be seen as an intensely hot body that is radiating energy into space in every direction just as the sun does. Would there be planets moving about it? No one can tell. It is so far away that planets like those which move around the sun would be invisible even with the most powerful telescopes. There is no reason for saying that there are no planets about Alpha Centauri. All that can be said is that there is no evidence one way or the other.

Imagine for a moment that there are planets moving about Alpha Centauri. Imagine too that we are on one of these Alpha Centaurian planets looking off through space at the sun. From this distant Alpha Centaurian planet the sun would be seen as a bright star, just about as bright as Alpha Centauri is when seen from the earth. The planets of the solar system would be invisible, just as the planets of Alpha Centauri (if any) are invisible from the earth.

The sun is an average star

From this distant planet you would say that our sun is just an average star. Many stars would appear brighter than the sun, and many would not be so bright; for in size, in brightness, and in the temperature of its surface the sun is about an average star. To us on the earth it seems much brighter than the other stars, but this is only because it is nearer to us. Similarly with other stars. If they could be viewed from the same distance as the sun, they would be much like it.

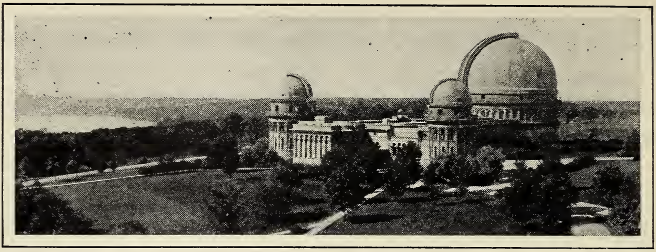


FIG. 24. The Work in Many Large Observatories such as this One is devoted to a Study of Far-Distant Space

This is the Yerkes Observatory, at Williams Bay, Wisconsin

B. What are the Conditions upon the Planets, and What determine the Conditions?

The earth and the other planets are very small when compared to the sun and the stars; but to us the earth is important, for it is the home of all the living things we know. Some of the other planets are in some respects quite similar to the earth. People have always wondered about conditions that exist on them. The planets are of course very much closer to us than the stars. With the development of science, astronomers working in observatories such as the one shown in Fig. 24 have found out a great deal about the physical conditions on them. The earth is neither the largest nor the smallest of the planets. It is neither the hottest nor the coldest, and neither the nearest to the sun nor the most distant.

Let us consider conditions on some of the other planets.

Mercury is nearest the sun

You will recall, of course, that the planet nearest the sun is Mercury. Its average distance from the sun is about thirty-two million miles. Notice in Fig. 22 that Mercury is very small as compared with the other planets, having a diameter of about thirty-one hundred miles. Because it is so near the sun, and again because it is so small, it is difficult to see Mercury except

by close observation. The planet was named Mercury after the swift-footed messenger of the Roman gods. Perhaps you can tell why.

Mercury makes one complete revolution around the sun every eighty-eight days. It rotates once on its axis in the same period. Since it revolves and rotates in just the same time, the same surface is always exposed to the sun's rays. Thus one side is always exposed to intensely bright sunshine, and the other side is always in darkness. Since Mercury is close to the sun, you would expect it to be hot. Scientists estimate that the side turned toward the sun is as hot as melted tin (about 400° F.). The temperature of the side turned away from the sun is probably as cold as dry ice (– 110° F.).

The quantity of matter (commonly called the mass) of Mercury is very small in comparison with the earth; in fact, it is but one twenty-fifth that of our own planet. The force of gravity on this small body, therefore, is much less than on the earth.

The weight of an object on the earth is the force of the earth's attraction for it. Similarly you may think of the weight of an object on a planet as the force of the planet's attraction for the object. The weight of an object is simply the force that is required to lift it. An object on Mercury would be attracted to the planet with a force only one fourth as great as that with which the same object would be attracted to the earth. Therefore only one fourth as much force would be required to lift it. If a boy weighs 120 pounds on the earth, he would weigh but 30 pounds on Mercury. If this boy were to jump with all the force he had, he could jump four times as high on Mercury as he could on the earth.

Do you suppose there could be an atmosphere about Mercury as there is about the earth? Remember that the tiny particles, or molecules, of gases are always in motion and that they would fly off from the earth if the force of gravity did not hold them back. As a matter of fact,

molecules of hydrogen and helium move with so much speed that the force of gravity is barely sufficient to hold them on the earth. Thus some hydrogen and helium are continually leaving the earth. Mercury is so small and its gravitational force is so slight that no gases can be held on its surface. Therefore this planet cannot have an atmosphere.

Mercury does not have an atmosphere

It is impossible to believe that there can be any form of life on Mercury. It is too hot on the side exposed to sunlight and too cold on the dark side. Even if other conditions were favorable, there could be no life where there is no atmosphere.

Of all the planets Venus is apparently most like the earth. Its diameter is only a little less than the diameter of the earth, and the force of gravity on Venus is 0.88 as great as the force of gravity on the earth. For this reason an object that weighs 120 pounds on the earth would weigh 0.88 of 120 pounds, or about 105 pounds, on Venus. The planet revolves around the sun in a period of about two hundred and twenty-five days. Venus has an atmosphere; in fact, its atmosphere is so dense that the surface of the planet cannot be seen. Since its surface cannot be seen, there is no way to tell how fast the planet is rotating. More heat reaches Venus than reaches the earth because it is only two thirds as far from the sun to Venus as it is from the sun to the earth. Its thick blanket of clouds protects its surface from the sunlight to such an extent that its surface temperature may be but little higher than the surface temperature of the earth.

In some ways conditions on Venus seem to be favorable for life. There is an atmosphere, although no one knows of what it is composed. Venus certainly turns on an axis, although no one knows how long it takes for one complete rotation. There is some evidence that a period of about thirty days is required. This would mean that the interval

Conditions on Venus may be favorable to life

between sunrise and sunset would be equal to about fifteen days as time is measured on the earth.

What else is known about Venus? It is reasonably certain that it is composed of the same chemical elements as compose the earth. These elements would probably form rocks that are similar to the rocks on the earth. The work of running water, of freezing, and of thawing would convert these rocks into soil; and if the rocks are like those on the earth, the soil would be like the soil on the earth. The average temperature is higher than on the earth; but the temperature over much of the surface of Venus is probably less than the temperature of our equatorial rain forests, where life is certainly abundant.

If you could imagine that there is life on Venus, it would be difficult to imagine what kind of life it would be. We should think first of life like that with which we are familiar; but there is really no reason why life, if it did exist on Venus, would be like the life on the earth. With all the uncertainties it is still possible to imagine that there are intelligent beings living under the clouds of Venus. It is possible that they live on a soil similar to the soil of the earth, that they use plants for food and thus get the energy that is necessary for life and growth, and that the plants use the energy from sunlight in the process of food-making.

The physical conditions on the earth, as on the other planets, are determined in part by its distance from the sun. The sun's rays are less intense on the earth than on Venus and more intense than on Mars. Living things on the earth are adapted to live in these physical conditions. Therefore to us these conditions seem just right. If there were living things on Venus and they could be transferred to the earth, they would probably find the climate here too cold for them. For the same reason we should probably find the climate uncomfortably cold if we were transferred to Mars.

The earth moves around the sun once in about three hundred sixty-five and one-fourth days. Our day of twenty-

four hours is the time required for the earth to turn once on its axis. Thus it rotates three hundred sixty-five and one-fourth times while making one complete revolution.

The earth rotates on an inclined axis

This fact, as you will see later, is of great importance. Another factor that determines in part the physical conditions on the earth is the fact that the axis on which it turns is not vertical to the plane in which it revolves but is tipped to an angle of $23\frac{1}{2}$ degrees, as shown in Fig. 25. At the present time the axis points almost in the direction of the North Star, but the direction toward which it points is slowly changing. In about twelve thousand years the axis will point toward Vega, the bright star which may be seen soon after sunset in September and October in a position that is directly overhead. The angle of the axis with the plane of the earth's orbit does not change, so this change in the direction in which the axis points will have no noticeable effect on the physical conditions of the earth.

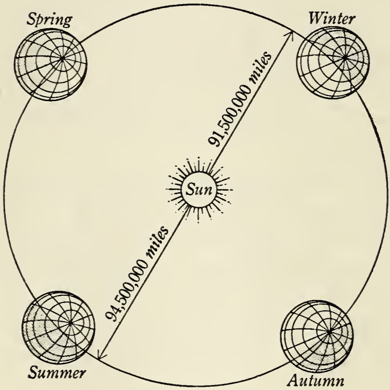


Fig. 25. The Changing Positions of the Earth in its Orbit at Different Times of the Year affect Conditions on Earth

The axis of the earth is inclined at an angle of $23\frac{1}{2}$ degrees to the plane of its orbit

Why is this inclination, or tipping, of the earth's axis important? This will be discussed at greater length later, but you should understand that because the axis is inclined at an angle of $23\frac{1}{2}$ degrees we have the seasons and the continuous change in the length of day and night. The position of the earth's axis at one time of the year is just about parallel to its position at any other time of the year.

When the earth is in a position in its orbit so that the axis is inclined away from the sun (as shown in Fig. 25), more sunlight falls on the part of the earth that is south of the equator. At this time it is summer in the Southern Hemisphere, and days there are longer than nights. Six months later the earth is in a position so that the inclination of the axis is toward the sun. At this time more sunlight falls on the Northern Hemisphere. The days here are longer than the nights, and it is summer. As the earth moves around its orbit, it changes from a position in which more heat from the sun falls on the Northern Hemisphere to a position in which more heat falls on the Southern Hemisphere. This causes the change from summer to winter. At a position halfway between these extremes an equal amount of heat reaches both the Northern and Southern hemispheres. When this time comes following our summer, it is fall; and when it comes just before our summer, it is spring.

The inclination of the earth's axis plays an important part in seasonal changes

This brief study of the changing seasons will help you to compare conditions on the earth with conditions on other planets. At a later time you will study the effects of the seasons at greater length. Let us continue now with our comparison of physical conditions on the earth with physical conditions on other planets.

The planet next beyond the earth is Mars. It is about fifty million miles farther from the sun than the earth is from the sun. Its diameter, about four thousand miles, is only half that of the earth, and its mass is only about one ninth as great as the mass of the earth. The force of gravity on Mars is only 0.38 as much as the force of gravity on the earth. The boy that weighs 120 pounds on the earth would weigh about 45 pounds on Mars. If he could jump 5 feet high on the earth, he could jump about 18 feet high on Mars with the same effort. Look at Fig. 26.

Mars is much smaller than the earth

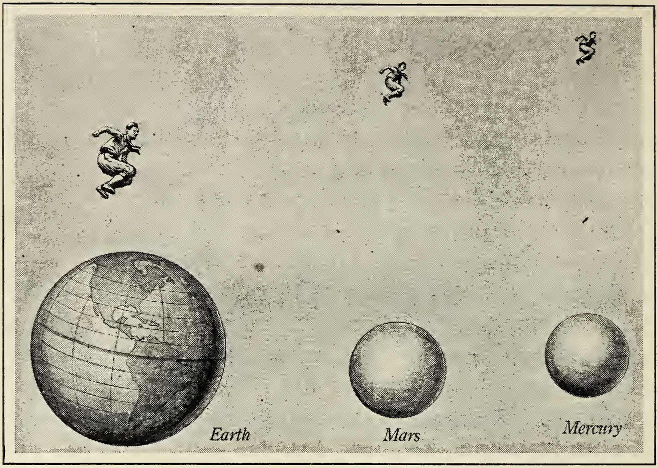


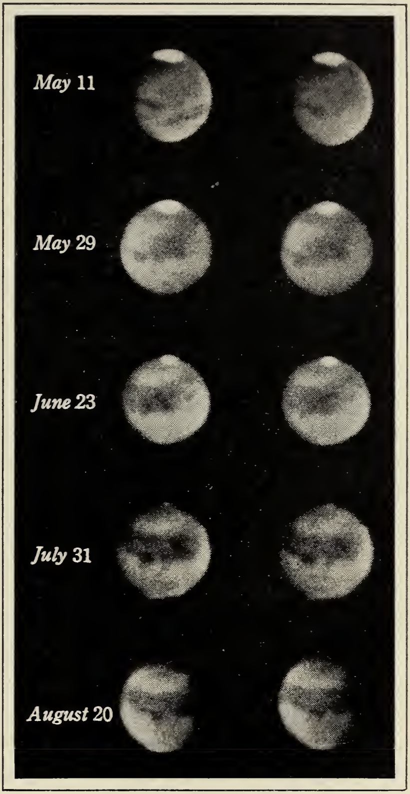
Fig. 26. On Which Planet would you rather be a High-Jumper?

Mars rotates on an axis and has seasonal changes

Mars makes one revolution in six hundred and eighty-seven days and rotates once in about twenty-four and one-half hours. Thus the Martian year is much longer than ours, although the Martian day is of about the same length. The axis of Mars is inclined from a vertical position to the plane in which it revolves around the sun to about the same extent as the axis of the earth is inclined from a vertical position to its plane. At one position in its orbit the axis is inclined away from the sun, and in another position it is inclined toward the sun. There is therefore a change in the seasons on Mars just as there is on the earth. Since a period of six hundred and eighty-seven days is required for this planet to revolve around the sun, the seasons on Mars would be about one hundred and seventy-two days long ($\frac{1}{4} \times 687$). On the earth, as you know, the seasons are about ninety-one days long ($\frac{1}{4} \times 365\frac{1}{4}$).

The physical conditions on Mars are determined by its distance from the sun, the length of its year and the length

of its day, its mass, the force of gravity on its surface, and the inclination of its axis. Since Mars is farther away from the sun, the intensity of the sun's rays on its surface must be less than on the earth. The seasons are longer; so the extremes of temperature between summer and winter must be greater. The surface gravity is only a little more than one third as great as on the earth, because the mass is less than the mass of the earth; the atmosphere that surrounds it must therefore be less dense. Mars has an atmosphere, but there is direct evidence that it is not as dense as the atmosphere of Venus or the atmosphere of the earth. With a good telescope the surface of Mars may be seen through its atmosphere. In this respect Mars is not at all like Venus; for, as you have learned, the atmosphere of Venus is so dense that the surface of the planet can never be seen through it.



E. C. Slipher, Lowell Observatory

Fig. 27. The Polar Caps on Mars change as the Seasons Come and Go

Certain definite changes may be seen to take place on Mars as winter comes and goes. Photographs taken through

telescopes during a Martian winter show polar caps of some kind. These disappear as the Martian summer approaches. Study the series of pictures in Fig. 27. Some think that these polar caps are formed of snow. It seems certain that they are formed from some sort of precipitation that comes out of the Martian atmosphere. Some astronomers think that there may be life on this planet. The appearance of the surface of the planet changes somewhat as the seasons come and go, and some have suggested that this change may be due to changes in the appearance of vegetation as the seasons change from summer to winter.

Conditions on Mars may be favorable for life

There are many peculiar markings on Mars that are plainly visible through large telescopes. There was a time when some astronomers believed that these markings were canals dug through desert regions by intelligent beings, to be used for irrigation. Neither the truth nor the lack of truth of this belief has been established, and in the absence of positive evidence astronomers generally refuse to accept it as true. It may be said with certainty that some of the conditions on Mars are at least in part favorable for life as we know it, but it may not be said with certainty that life really does exist there.

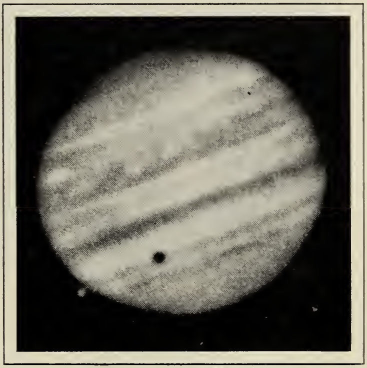
The next four of the sun's family of planets are very much larger and very much farther away from the sun than Mercury, Venus, Earth, or Mars. They differ from the earth in many respects.

Jupiter, shown in Fig. 28, is the largest of all the planets. Its volume is more than a thousand times the volume of the earth; and although it is fifteen times as far away as Venus, Jupiter appears nearly as bright in the sky. Jupiter revolves around the sun only once in nearly twelve years as time is measured on the earth, but rotates on its axis in less than ten hours. Its size, its distance from the sun, its period of revolution, and its period of rotation make physical conditions on

Jupiter is the largest of all the planets

Jupiter extremely different from physical conditions on the earth.

The mass of Jupiter is more than three hundred times that of the earth, and objects are attracted to its surface with a force that is more than two and one-half times the force that holds objects on the earth. The boy that weighs 120 pounds on Earth and 45 pounds on Mars would weigh 300 pounds on Jupiter. In the high jump he would be able to clear a bar only about two feet high. The intensity of the sunlight on Jupiter is only about one thirtieth as great as on the earth. This planet has nine moons; but since moonlight is reflected sunlight, its moonlight must be dim. The light is dim because Jupiter is very far away from the sun, being four hundred and eighty-three million miles distant. It is so far that it takes more than forty minutes for light to travel to this planet from the sun! The distance from Jupiter to the sun is more than five times the distance from the earth to the sun.



Mt. Wilson Observatory

Fig. 28. Jupiter is the Largest of the Planets

In the lower left-hand corner is shown one of the moons of Jupiter. The black spot on the surface of the planet is the shadow of this moon

It is comparatively easy to measure the length of a "day" on Jupiter, just as it is on Mars, because certain spots, or markings, appear always to be in the same place, and these can be observed as the planet rotates.

Because Jupiter is so far from the sun, it is certainly very cold there. Astronomers have found the temperature of its surface to be about − 250° F. This is colder than the freezing point of pure alcohol.

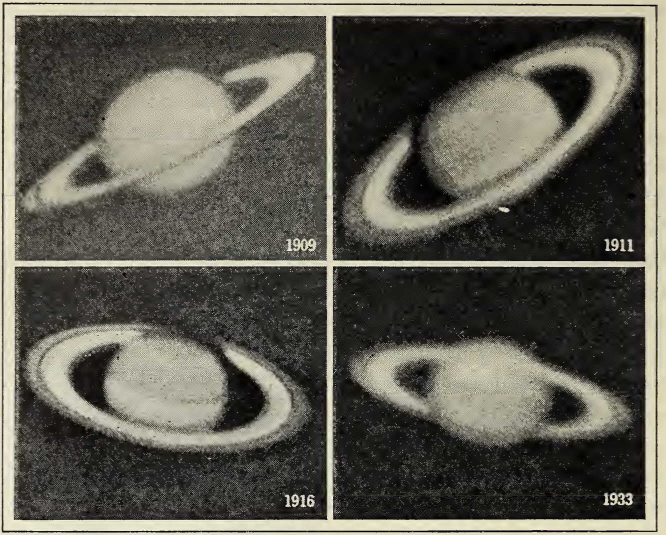


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FIG. 29. Saturn is the Planet with the Rings

Notice how the angle of the rings has changed during the intervals between the different photographs

Saturn is the planet with the rings

Saturn is the planet with the rings. If you have ever looked through a telescope at Saturn, you have probably seen these rings, as shown in Fig. 29. No one can describe exactly what they look like. These rings are really numerous fine particles, probably solid, proceeding around Saturn just as moons do. The rings seem very thin when compared to the diameter, which means that most of the particles revolve about the planet in the same plane. Besides its rings Saturn has nine moons. This planet is ten times as large as the earth and much farther away from the sun. The temperature on its surface is very much lower than the temperature on the earth, and it must be considerably lower than the temperature on Jupiter.

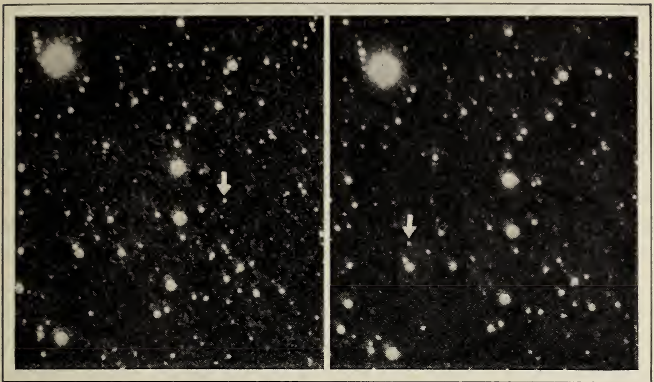

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FIG. 30. **Pluto is the Planet Farthest from the Sun**

An interval of six days elapsed between the two pictures. Can you find any evidence that Pluto is a planet?

The next planet beyond Saturn is Uranus. Its diameter is nearly four times the diameter of the earth, but it is so far away that it is but faintly visible to the naked eye. Sunlight on this distant planet is only one four-thousandth as intense as on the earth.

In the far distance beyond Uranus is Neptune, and still beyond Neptune is Pluto. Notice how faint this far-distant planet appears in Fig. 30. It is hard to imagine the physical conditions that exist at such a great distance from the source of light. Certainly the intensity of the sun's rays on these distant planets is very feeble.

All members of the solar system are composed of the same chemical elements

There is good evidence that all these bodies — the sun, the planets and their moons, the planetoids, the meteors, and the comets — are composed of the same chemical elements. The differences in the physical conditions on the planets are due to differences in their distances from the sun, the periods of rotation and revolution, the inclination of their axes (singular, *axis*), and their masses.

Let us summarize now some of the conclusions which may be drawn from these observations of the solar system.

The sun is a star of average brightness and average size. There are thousands of stars that are very much like it. All other stars are so far away that no one can tell, even with the most powerful telescopes, whether or not they have planets moving about them. Since other stars are like our sun, it seems reasonable to believe that other stars may be suns for other systems of planets. There is good evidence that all the stars are composed of about the same chemical elements. It is certain that the radiation from many stars is as intense as the radiation from our sun. The radiation from some stars is more intense; from others, less. The force of gravity of many stars is great enough to hold a system of planets in regular courses.

There may be other solar systems

There may be other systems of planets, and in these systems there may be planets on which conditions are favorable for life. We know that living things exist on the earth wherever conditions are favorable. It may be that life exists on the planets of other systems. If there be distant planets on which there is life, the living things live on a soil that is similar to the soil of the earth, for it is composed of the same chemical elements; and the energy that is necessary for life is radiated to these distant planets from the star which is their sun.

If there are such planets, the distance from the earth to them is so great that the limits of the solar system are extremely small in comparison. Yet it seems not unreasonable to think that there are such planets. In the vast spaces of the universe, where there are some billions of stars, there may be several stars that have systems of planets; and among these systems there may be several planets on which conditions are favorable for life. Certainly it is not safe to decide that all the life in the universe is on the earth. At the same time it must be recognized that no one can say with certainty that there is life anywhere else.

Distances in the solar system are so great that even the best observations do not show clearly the physical conditions on the planets. On some planets conditions may be somewhat similar to conditions on the earth. On other planets conditions are very different.

Can You Answer these Questions?

1. Why is it said that the sun is only an average star?

2. What evidence is there that the surface of the sun is composed of gases?

3. Why is it that the lighter gases, such as hydrogen and helium, are more abundant in the atmosphere of the sun than in that of the earth?

4. The same side of the planet Mercury is always exposed to the sun. Since the planet rotates, how is this possible?

5. How do you explain the absence of an atmosphere around Mercury?

6. In what respects is Venus like the earth?

7. What is the period of the earth's revolution? of its rotation?

8. Is there anything in the appearance of Mars which might lead to the conclusion that some forms of life exist there?

9. What are the causes of the differences in the physical conditions to be found on the various planets?

10. Jupiter is very large, but Venus usually appears larger and brighter. Why?

Questions for Discussion

1. Is it possible that there might be somewhere in the universe some form of life different from any on the earth? Is it possible that there might be creatures that breathe ammonia instead of oxygen, for example? Might there be creatures that wouldn't breathe at all?

2. How is it possible for the volume of the sun to be a million times that of the earth and yet its mass only three hundred and thirty-three thousand times greater than that of the earth?

3. Do you think that man's gradually increased knowledge of the solar system has made any difference in his ways of living or thinking?

4. If you were an astronomer starting out to seek other planets, how should you begin?

5. When bigger and better telescopes are made, what do you think they will show?

Here are Some Things You May Want to Do

1. Start a scrapbook of clippings about the planets, or make one section on planets in your astronomy scrapbook.

2. Imagine that you had a powerful rocket plane which could travel at a speed of five hundred miles per hour. How long would it take you to reach the different planets from the earth? Prepare a time-table for the Interplanetary Transportation Company, indicating the arrival and departure of the plane at the various planets.

3. A long time ago Jules Verne wrote a book called *From the Earth to the Moon and a Trip around It.* You may want to read it. Perhaps you may want to write a story of an imaginary trip to Venus or to some other member of the solar system. In telling your story use whatever facts you now have.

4. Look up some of the athletic records for high jumping, broad jumping, or pole vaulting. See if you can figure what some of these records would be on some of the other planets.

5. Make a study of and report on some of the great telescopes of the world.

6. Perhaps you would like to make a telescope of your own. If you will read pages 319–322 of Darrow's *Boys' Own Book of Science* you will find some suggestions for doing this.

Chapter IV · What are the Physical Conditions on the Surface of the Moon? What Effect has the Moon upon the Earth?

FIG. 31. "The full moon sheds its silver glow upon rippling waters . . ."

Have you ever stood upon the shore of a river and, looking eastward, seen the moon in its reflected glory as shown in Fig. 31? Imagine yourself on the western shore of this wide river. It is early evening, and you have watched the moon rise above the distant mountains. At first only the edge of its round surface is visible. Gradually, as the earth turns, more and more of the moon's surface appears, and soon its full face is revealed. As time passes it rises higher in the sky.

The sun of course has set, but you know that far to the west of where you are it is shining on the surface of the earth with the same brightness with which it shone only a

few hours before at the point where you now stand. The surrounding landscape is now bathed in brilliant moonlight, and familiar objects have taken on new colors and forms.

How close the moon appears to be at such a time! And yet it is some two hundred and thirty-eight thousand miles away. This is a rather short distance, it is true, when compared with the space of ninety-three million miles between the earth and the sun. Yet it is a great distance as we measure distance upon the earth.

The moon is about two hundred and thirty-eight thousand miles from the earth

As you look into the face of the full moon you are in a position that is in line with the moon and the sun. In this position all of the lighted surface of the moon is visible. The brightness of the moon is due to the light from the sun falling upon its surface. The moon itself is a dark object and would be quite invisible if it were not for the rays of the sun upon it. When you see this relationship, you realize that the light that plays upon the water as you gaze across the river toward the moon is light that has traveled through space from the sun to the moon, has been reflected from the moon to the water of the river, and from the water to your eyes.

The moon shines by reflected light

In the stories which have come from the past you may find that people who lived long ago also were moved by the sight of the changing moon and wondered about this close neighbor of the earth. What was the moon? What were conditions like up there? What was "the man in the moon"?

Their curiosity, however, could not be satisfied through scientific knowledge. Their explanation of the moon, like their explanations of many observations of the solar system, was made in terms of superstitious beliefs. Today, however, with the aid of powerful telescopes and careful scientific study, man has secured answers to many of these questions.

If you could look at the surface of the moon through a telescope, you would see a picture similar to the one shown in Fig. 32. The telescope shows high mountains and level plains. Scattered over the moon's surface are large hollows surrounded by circular elevations. These are called lunar craters because it was once thought that they were craters of extinct volcanoes. Today many astronomers believe that these enormous holes were made by falling meteors. The moon, like the earth, is continuously bombarded by meteors that come in from outer space. Since there is no atmosphere on the moon to burn them up, they fall into the moon with great force. The striking of these meteors against the surface is a force tending to wear down the lunar mountains and convert them into rock and dust.

There are mountains on the moon

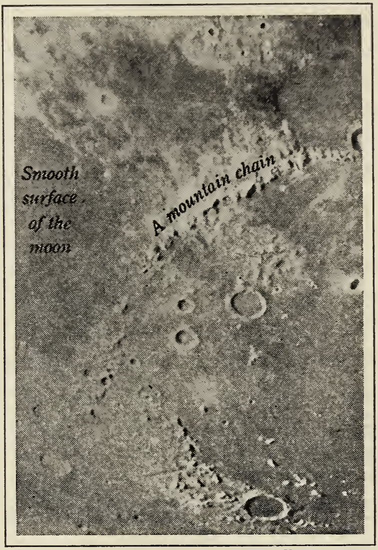

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Fig. 32. The Surface of the Moon, viewed through a Powerful Telescope, presents a very Uneven Appearance

The moon is much smaller than the earth, being only 2160 miles in diameter; but the mountains on its surface rival in height those on the earth, its loftiest peaks being about 25,000 feet high. Fig. 32 shows craters and a chain of mountains.

There are no water and no atmosphere on the moon. Because it is so small, its attraction of gravity is not sufficient to prevent gases or liquids from escaping if there

ever were any upon the moon's surface. Since there is neither air nor water on the moon, the changes such as those caused on the earth by running water and the force of wind cannot take place. The surface of the moon is a desert, drier than any desert on the earth. The flat places are covered with dust, but there is no wind to stir it up and no water to moisten it.

The force of gravity on the moon is less than on the earth

Suppose you were out in space looking at the earth with long-distance eyes. If you watched it for a period of twenty-four hours, you would see its entire surface as the earth rotated on its axis. You would see the patterns of all the continents of the earth during this twenty-four-hour period of rotation, together with all the oceans, plains, and other physical features. But how is it, then, that you never see more than the one pattern on the face of the moon — the one that gives rise to our popular "man in the moon"? This pattern does not change. If the rotation of the moon on its axis were similar to that of the earth, you should see all the surface of the moon as it turned. As it is, you see only one side. Does this mean that the moon does not rotate? You might reach this conclusion; but it is not strictly true, for the moon does rotate on an axis. The reason you do not see more than one side of the moon at any time lies in the fact that the period of rotation is the same as the period of revolution. The moon, therefore, always keeps the same face toward the earth, turning just fast enough to keep this one side of its surface exposed to our view.

The moon rotates but once during each revolution

You may illustrate the manner in which the moon turns if you will stand facing a chair and then walk "sidewise" around the chair, keeping your face all the time toward the chair. In this manner you "revolve" around the chair as the moon revolves around the earth. During one revolution you have "rotated" once. An observer in the chair sees only one side of you as you "revolve" and "rotate."

In an interval of about four weeks the moon revolves around the earth, and in this same interval it rotates once. The sun's rays are of course falling upon the moon. As the moon turns, the rays slowly creep around its surface. The period of sunlight on the moon is an interval of two weeks, and the period of darkness is equally long.

Where the rays of the sun strike the surface of the moon, the heat is intense, since neither clouds nor air dim their intensity. On the dark side of the moon and within the shadows of the mountains it is extremely cold, for heat is lost rapidly from the surface. As the moon turns on its axis, a spot upon its surface may be heated by the sun to a temperature higher than that of boiling water, and cooled when in darkness to the temperature of liquid air.

The moon is a lifeless mass

Life in an environment such as that pictured on the moon would be impossible. The moon and the earth are probably composed of the same chemical elements, but the physical conditions on the moon are very different. In fact, you can safely decide that the moon you see over the eastern horizon is merely the surface of a lifeless mass lighted by the rays from the sun.

A. What is the Cause of the Phases of the Moon?

The time of moonrise changes

If you watch the moon for several nights in succession, you will observe certain interesting changes that take place. One of these changes is the time change. Each night the moon will appear to rise in the east about fifty minutes later than it did the night before. Why is this?

The interval between full moon and full moon again is about twenty-nine days (more accurately, twenty-nine and a half days). In this interval the earth has moved about one twelfth of the distance around its orbit and has turned twenty-nine times on its axis. The moon has two forward motions. It revolves around the earth, moving in the same

direction as the earth turns on its axis, and it moves with the earth around the sun. The moon moves one twenty-ninth of the distance it must move between one full moon and the next full moon while the earth rotates once, that is, in twenty-four hours. A point on the earth from which you watch the moonrise must move through one rotation and one twenty-ninth of another rotation before you are in a position to see the next moonrise. The earth makes one twenty-ninth of a rotation in about fifty minutes (the 1440 minutes in 24 hours $\div 29\frac{1}{2} = 48.7$). It is for this reason that the moon rises about fifty minutes later on one evening than it did on the evening before.

Another interesting observation is the changing appearance of the lighted part of the moon which is visible to us. This is also due to the motions of the earth and the revolution of the moon. These changes are called the phases of the moon. It should be easy to understand that when the moon moves around to a position between the earth and the sun you cannot see the moon. The light from the sun is too brilliant. Besides, the side of the moon which is turned toward the earth is not receiving sunlight. This is called the new-moon phase.

The moon shows phases

As the moon moves forward in its orbit, it continually changes its position in relation to both the earth and the sun. At new moon the earth, the sun, and the moon are in nearly the same straight line, as shown in Fig. 33. The sun is shining on the surface that is turned away from us, and we see none of the lighted surface. As the moon moves along in its orbit in the direction indicated by the arrow, more and more of the side of the moon which is turned toward the earth comes into the light of the sun. These changes in the amount of surface upon which the sunlight falls causes the moon's phases.

Certain phases have definite names. You will find in a calendar the dates for new moon, first quarter, full moon, and last quarter. The interval between each of these phases

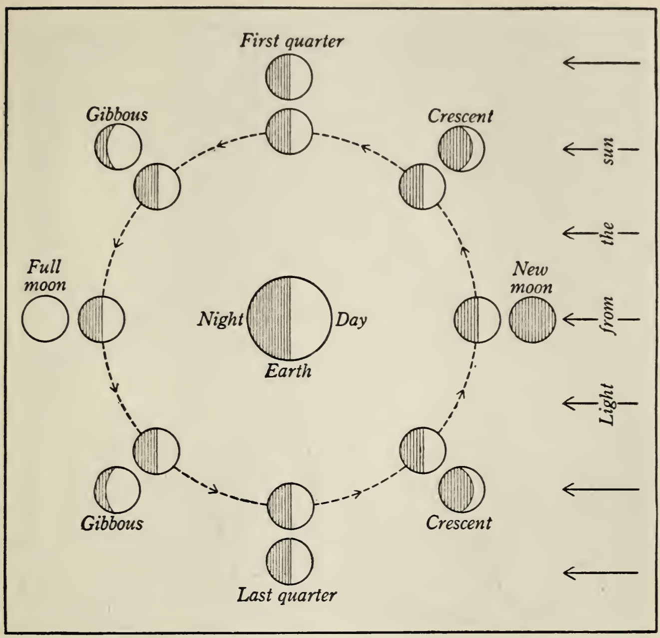

FIG. 33. The Different Phases of the Moon are caused by Changing Relationships in the Position of the Sun, Moon, and Earth

The dotted line represents the orbit of the moon around the earth. The outlines of the moon in its orbit illustrate the position of the lighted surface of the moon in relation to the earth. The outlines outside the dotted line illustrate the appearance of the moon from the earth at the times indicated. (Redrawn from Barton and Barton's *A Guide to the Constellations*. Courtesy of the McGraw-Hill Book Company, Inc.)

is a little more than seven days. Fig. 34 shows these four phases, and it shows also the gibbous and crescent phases.

Immediately following new moon comes the new crescent, seen only in the western sky soon after sunset. Following the new crescent the moon is seen higher and higher in the sky as the evenings pass. At first quarter the moon appears high in the sky at the time of sunset. Seven days later the full moon is over the eastern horizon at sunset.

Lowell Observatory (upper right) Yerkes Observatory (lower left and right)

Fig. 34. As we look at the Moon, we see Different Phases

Study Fig. 33 again and see if you can determine the conditions which cause the differences in appearance pictured here

If you could stay up until midnight about one week after full moon, you would see the moon in last quarter rising in the east. By sunrise the moon in last quarter would be near to a north and south line directly overhead, and it would set in the west about noon. About seven days later the moon may be seen in the east just before sunrise, again as a crescent. This is the old, or last, crescent and is the phase just before new moon. This old crescent is just as beautiful as the new crescent which is seen so often just after the sun sets. We are not so familiar with the old crescent, however, for it rises in the east at a time when we are usually asleep.

The same phase of the moon is observed on all parts of the earth in the course of the earth's daily rotation.

While observing the new crescent you may notice that, when only a small part is brightly lighted, still you may see in rather dim outline the remaining round surface of the moon (note Fig. 35). Why should this be? Since the moon is a dark object, light from some source must be falling upon it; else it could not be seen. If you could imagine how the earth would look when seen from the moon, you could understand the source of the light. The earth is lighted by the sun just as the moon is lighted by the sun. The diameter of the earth, however, is more than three and six-tenths times the diameter of the moon, and its surface is more than thirteen times greater than the surface of the moon. Thus the earth seen from the moon would appear as a lighted ball thirteen times as large as the moon seems to be when viewed from the earth. At the time of new moon the fully lighted surface of the earth is turned toward the moon, and the sunlight which it reflects lights the dark surface of the moon. The surface of the moon is lighted more brilliantly by earthlight than the earth is ever lighted by moonlight.

Lowell Observatory

FIG. 35. At New Moon the Surface of the Moon that is turned toward the Earth is lighted more brilliantly by Earthlight than the Earth is ever lighted by Moonlight. This Picture was taken when the Moon and the Planet Venus were near Each Other. Why does Venus look so much Smaller than the Moon?

The dark surface of the crescent moon is lighted by reflection from the earth

B. What causes an Eclipse?

If you have ever seen one, you would surely include an eclipse of the sun as among the most spectacular events you have ever witnessed. For weeks and even months before, you read in the daily papers and magazines of the coming event. You are told that at a certain time on a certain day the light of the sun is to be blotted out. Those of you who have been fortunate enough to experience this event before may put on an air of superior knowledge as you confirm the predictions made by the newspapers. "Will the sun really disappear from sight?" you are asked. "Yes," you assure your less knowing friends. "And will the stars really come out during the daytime?" "Oh, yes!" you say. And then you finally close with, "Just wait and see!"

Some studies of the sun can be made only during a total eclipse

The great day comes. People are busy smoking pieces of glass over candles, for they have been told that they must not look at the sun without some protection for their eyes. The more foresighted ones have purchased colored spectacles or have secured exposed camera film. Amateur photographers have spent much time discussing whether or not it is possible to take pictures of the eclipse with an inexpensive camera; and friends (amateurs too) advise them that it is possible or perhaps that it is not. Finally the amateur photographer decides he will try. But certain people have made far more expensive and elaborate preparations. Colleges and other institutions of learning have sent scientists sometimes over great distances to make observations and studies of the event. Cameras have been built and attached to large telescopes as illustrated in Fig. 36. Many men have been drilled day after day so that when the great moment comes they will do without wasting an instant all the things they are supposed to do.

To an observer the first evidence of an eclipse comes

FIG. 36. Special Equipment is used by Scientists when they study Eclipses

This special set of instruments was set up in Maine to help in the observation of the 1932 eclipse

when he sees, through smoked glass, that a small bit of the sun is cut off. The moon is quite invisible in the intense rays of the sun; but you know it is there, for it has cut off some of the sun's light. As time passes, more and more of the sun seems to be cut off and it narrows to a fine crescent. Study the series of pictures in Fig. 37. In the meantime the air grows cooler and darkness seems to be coming on. There is an unusual light effect, and things take on a strange appearance. The light grows dimmer until the moon completely covers the surface of the sun. Now it is so dark that stars appear. Mercury, always near the sun, shines out brightly. We learn from observation that the stars are in the sky during the day just as at night, for they come into view when the bright rays of the sun are cut off.

Stars may be seen in the sky during the day

While the sun is covered, the brilliant rim of light that surrounds it, known as the corona, comes into view. It is illustrated in Fig. 38. As we gaze at this corona we see evidence that mighty forces are at work there. Evidently there is an atmosphere on the sun, and terrific forces keep it continuously moving. You wish you could continue these

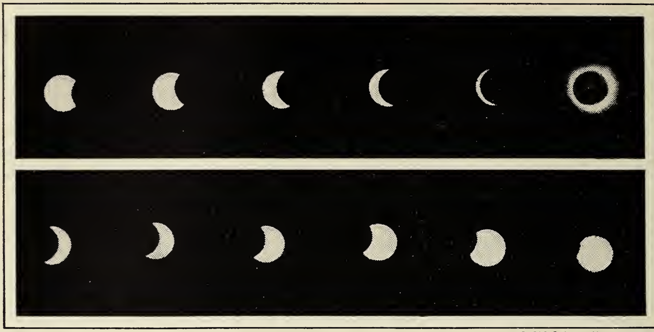

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FIG. 37. During a Solar Eclipse the Sun changes in Appearance as shown Above

This illustration pictures the progress of an eclipse of the sun. The photographs were taken at short intervals. Was this eclipse a total one?

observations, but the hundred seconds or so of totality, when the sun is completely hidden, soon pass. The moon moves on across the face of the sun, and the bright rays of the sun come out from behind it. In about an hour the full face of the sun is uncovered and the eclipse is over, for the dark shadow of the moon has passed off into space.

There are historical accounts that tell how primitive men and women were terrified during an eclipse. If you have ever seen a total eclipse of the sun, you may easily understand why they were frightened. The dimming daylight in midday, the strange appearance of the landscape, and finally the complete covering of the sun and the appearance of the stars may well seem to ignorant people as an interruption in the course of natural events. Today its causes are well understood, however, and no one fears an eclipse. In truth, the passing of an eclipse exerts no more influence on the welfare of man than the passing of a cloud.

An eclipse of the sun occurs when the moon, in passing between the earth and the sun, shuts off the light from the sun. Let us explain this a little more fully.

Observatory of the University of Michigan

FIG. 38. The Solar Corona gives Evidence that Mighty Forces keep the Atmosphere of the Sun in Continuous Motion

The moon's path around the earth and the earth's path around the sun are not in the same plane. The two planes cross each other at an angle of about five degrees. Streaming out into space from the dark side of the moon and from the dark side of the earth are dark cone-shaped shadows. These shadows are of course the regions from which the rays of the sun are cut off. If these bodies were in the same plane, they would come into exactly the same straight line at every new moon and at every full moon. With these three bodies in the same straight line and the moon between the sun and the earth, the earth would pass into the moon's shadow and there would be an eclipse of the sun. Notice from the picture, however, that the moon's shadow would cover only a small part of the earth's surface. For an observer in the path of the shadow there would be a total eclipse of the sun.

During an eclipse of the sun the shadow of the moon passes over the earth

S

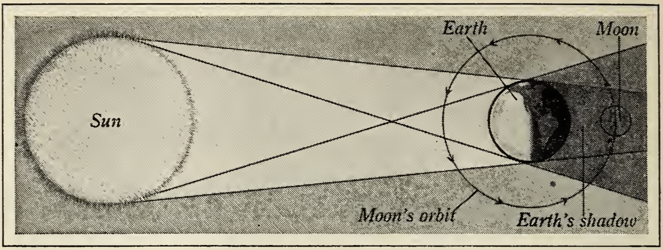


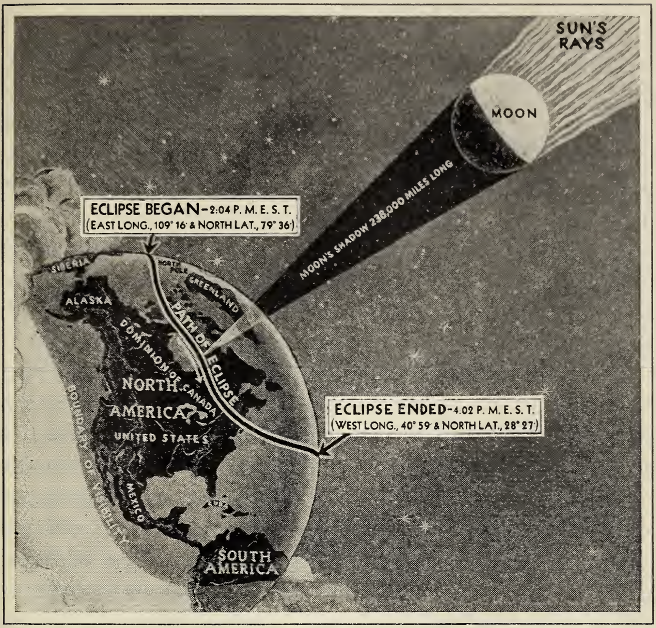
Fig. 39. An Eclipse of the Moon takes place when the Sun, Earth, and Moon are in a Straight Line

Why is every eclipse of the moon a total eclipse?

The shadow of the earth causes an eclipse of the moon

When these three bodies are in line and the earth is between the moon and the sun, as in Fig. 39, the shadow of the earth falls upon the moon. The earth is much larger than the moon, and its shadow on the moon may cover the face of the moon completely. When the moon is eclipsed, it may be seen as a total eclipse from any position on the earth from which the moon is visible. When there is an eclipse of the sun, it can be seen only along a narrow strip of the earth's surface. An eclipse of the moon can occur only at full moon, and an eclipse of the sun can occur only at new moon.

The diagram in Fig. 40 shows the conditions under which an eclipse of the sun occurred on August 31, 1932. It was visible as a total eclipse in New England along a strip of the earth's surface about a hundred miles wide. It was visible as a partial eclipse over the whole of the continent of North America. As you see from this diagram, there is always the region, behind the moon from the sun, which is in darkness, and the long pointed shadow stretches off into space. The moon is two hundred and thirty-eight thousand miles from the earth, and you may see from the picture that this is just about the length of this shadow. If the moon were much farther from us, the black shadow



New York Times

Fig. 40. A Solar Eclipse takes place when the Moon passes between the Earth and the Sun

Why should the path of the eclipse be a curved one?

would not reach the earth, and a total eclipse would be impossible. If the moon were farther away or a little smaller, it would seem to pass across the face of the sun, but it would not cut off all the light. Since the distance between the earth and the moon changes a little, there are eclipses during which the dark shadow does not reach the earth.

When the earth and the moon are closest to each other and when other conditions are just right, an eclipse may be total as long as seven minutes and fifty-eight seconds. You may see from the picture that, if the moon is closer, more

of the earth's surface will be covered by the shadow. Consequently a particular spot will be in the shadow longer as the earth turns under it. The eclipse of 1923 remained total for nearly a hundred seconds.

The picture shows that the eclipse began near the north pole. Since the earth is turning on its axis and the moon is moving about the earth, the tip of the shadow will move along rapidly. During this eclipse the shadow moved on the surface of the earth at about 2000 miles per hour. It covered the distance between the place where it first struck the earth and the position at which it passed off the earth, far out over the Atlantic Ocean, in about two hours. It is hard to understand why it moved so fast. But remember, the surface of the earth where you live is moving more than 800 miles an hour as the earth turns. And then, too, the earth moves round the sun and the moon round the earth.

Dates of future eclipses can be foretold

The movements of the earth and of the moon are so well known that the time of future eclipses may be told with very great accuracy. An eclipse of February 14, 1934, was visible only over the Pacific Ocean. One on July 9, 1945, and one on June 30, 1954, will be visible in Canada. The next eclipse visible in the United States will be on July 20, 1963, and at that time the path of totality will again pass over New England.

Dates of past eclipses can be figured

Similarly, astronomers may figure accurately the dates of eclipses that have occurred in the past. Herodotus, an ancient historian, tells of a battle between the Medes and the Lydians which was interrupted by an eclipse. The eclipse so terrified the armies that they quit fighting and made peace. The frontispiece to this book presents an artist's idea of this scene. Astronomers tell us that the date of this battle must have been May 28, 585 B.C., for on this date the position at which Herodotus said the battle took place was in total eclipse.

C. What causes Tides?

Everyone who lives near the ocean knows something of the tides, although at some places along the shore the difference between high tide and low tide is very little. Along the coast of Florida the difference between high tide and low tide is about one foot, but at the head of the Bay of Fundy in eastern Canada the tide sometimes rises more than fifty feet. This is an unusually high tide — one of the highest in the world. In Florida the tide is of but little concern to the people who live along the ocean. It does not noticeably affect either commerce or bathing. Along the shores of the Bay of Fundy in Canada, however, the tide is an extremely important feature of the environment. When the tide is low, a traveler through this region may see along the bay thousands of acres of land that have no trees or grass. These are the tidal flats. This land slopes off gradually to the water, which may be many yards away. As you walk over this land, it is obvious that it has been covered with water quite recently. There may be an abundance of seaweeds, black mussels, starfish, and jellyfish distributed over it. Occasionally large sea animals, even small whales, are left on the tidal flats when the tide goes out.

Tides are not all the same height

In some places tides have great effects upon life

If you were standing along the shores of the bay, you would soon become conscious of the fact that the level of the water changes. If the tide was coming in over a long stretch of gently sloping country, you might find it necessary to keep moving out of its way. The average interval between high tide and low tide is six hours. The position where you may have stood near the edge of the water when the tide was out may be covered six hours later by water to a depth of about fifty feet.

This rapid rush of water makes a great spectacle as it comes and goes through narrow inlets. At the head of the

Fig. 41. In the Bay of Fundy the Tide sometimes rises more than Fifty Feet

This picture shows the tidal wave entering the narrow inlet of a river at the head of the Bay of Fundy

Bay of Fundy in New Brunswick there is a mouth of a river up which the tide rises. As the tide enters this narrow inlet, the water rises so rapidly that it flows up the river as a high wave (see Fig. 41). Such a wave of water is called a tidal bore. The bore flows past an observer on the shore in an interval of about four minutes. During this interval the water may rise as much as six or eight feet. Boat and ferry schedules depend upon the tides. At low tides these vessels are not afloat. They rest upon the mud flats at the wharves where the water left them as the tide went out. It is a great experience to stand at the edge of these tidal flats and watch the tide come toward you. You may see the vessels, one after another, lifted from the mud and set afloat as the water rises around them. This is an example of a powerful force acting upon the surface of the earth.

There are other regions of very high tides. In the Bristol Channel, on the southwest coast of England, the tide rises

more than forty feet. The mouth of the Amazon River in South America is another region of high tide. A tidal bore sometimes reaching a height of twelve feet moves up this great river.

What causes this change in the level of the water? The answer to this question may be found by considering the force of gravity. The effects of this force have been mentioned and demonstrated before. You have seen that the sun attracts the earth and the other heavenly bodies and holds them in their orbits. You have seen that the same thing is true in relation to the earth and the moon. Accordingly you expect the moon and the earth to attract each other. Such is the case, and this is the principal factor in the cause of tides. As the earth rotates on its axis, one place after another on the earth comes under the gravitational force of the moon. The gravitational pull of the moon is not equal at different positions on the surface of the earth. It is greatest at the point closest to the moon and least at the point farthest from the moon. These unequal forces tend to stretch the earth a little. The rigid earth does not change much in response to these different pulls, but the water on the surface of the earth, being freer to move, does. The water that is closest to the moon is attracted the most, and the water that is farthest from the moon is attracted the least. This causes a bulge on opposite sides of the earth. This is illustrated in Fig. 42.

Tides are caused by gravitational force

This bulge is the tide. Since the earth is turning on its axis, one tide moves along over the surface of the earth, moving from west to east. There is another tide, not quite so high, on the opposite side of the earth, where the solid earth is pulled away from the water. Thus two high tides move along over the surface of the earth. Since the time between moonrise of one day and moonrise of the next is about twenty-four hours and

The height of the tides changes as the relative positions of the sun, moon, and earth change

fifty minutes, there are two high tides and two low tides in this interval.

The gravitational attraction of the sun also influences the tide; but since the sun is so far away, even though it is larger, its effect is not nearly so great as the effect of the moon. When the earth, the moon, and the sun are in the same straight line, as at new moon or at full moon, the sun and the moon are pulling together; and it is at this time that the tides are highest. When the moon is in a position such that a line from the earth to the moon is at right angles with a line from the earth to the sun, the rise of the tide is least. These different effects are shown in Fig. 42. In *a* and *b* the gravitational attraction between the earth, sun, and moon is in the same straight line. In *c* the line of gravitational attraction between the earth and the sun is at a right angle to the line of gravitational attraction between the earth and the moon. Notice the effect these changes in position have upon the tides. Highest and lowest tides come when sun, moon, and earth are in a straight line.

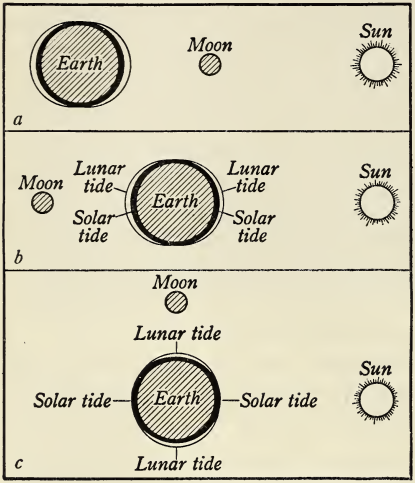


Fig. 42. Tides are caused by Gravitational Force

In *a* and *b* the gravitational attraction between the earth, sun, and moon is in the same straight line. In *c* the line of gravitational attraction between the earth and the sun is at a right angle to the line of gravitational attraction between the earth and the moon. Notice the effect these changes in position have upon the tides. (Redrawn from Tarr and Von Engeln's *New Physical Geography*. Courtesy of The Macmillan Company, Publishers)

D. Do Changes in the Moon affect the Weather or the Fortunes of People?

There are many beliefs about the moon that seem to be nothing more than superstition. We hear of dry moons and wet moons. It is often stated that there will be a change in the weather when the moon changes. Careful observations have been made in an effort to find a relationship between the moon and the weather, but none has been found. The moon attracts the earth and is attracted by the earth, and the moon is the chief cause of the tides; but there is no evidence that the moon affects the weather or the growth of living things on the earth. One observer states his conclusion in this manner:

The moon does not affect the weather

The moon and the weather
May change together,
But a change in the moon
Does not change the weather.

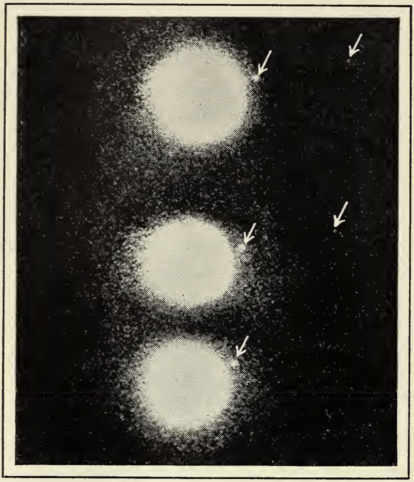
Fortune-tellers and such persons often make reference to the moon and the planets in practicing their trade among ignorant people. Such work is based either upon misunderstanding or upon deliberate fraud. There is no evidence which even suggests that the welfare of human beings is in any way affected by the phases of the moon or any other changes in it.

E. Are the Moons of Other Planets Similar to the Earth's Moon?

In your study of the other planets you have learned that some of them have one or more moons. Mars has two, but they are extremely tiny and only a short distance from the planet. You can get an idea of the size of one of these moons from Fig. 43. One is only ten miles in diameter, the other about five miles in

Other planets have moons

diameter. One is 3725 miles from the surface of Mars, the other is 12,475. These moons are held in their courses by the gravitational attraction between them and Mars. Neither of these moons is big enough to cause a total eclipse that would be visible on Mars, and they would not have much effect as the causes of tides.



E. C. Slipher, Lowell Observatory

FIG. 43. The Moons of Mars are extremely Tiny

These photographs of Mars, taken at three different times, show the moons of Mars. One is so small that it cannot be seen in the lower photograph

Three of Jupiter's nine moons are larger than the earth's moon, and a fourth is nearly as large. The other five are very much smaller. The larger ones are all farther from Jupiter than our own moon is from the earth, and Jupiter is much farther from the sun than we are, so that the intensity with which sunlight falls upon Jupiter and its moons is about one twenty-fifth the intensity of sunlight on the earth and its moon. With all its moons, the moonlight on Jupiter is certainly very dim. The light from the moons of Saturn and Uranus, too, is extremely dim. Light on the earth's moon is nine hundred times brighter than light on Neptune's moons and more than fifteen hundred times brighter than the light on Pluto.

Thus you can feel sure that the picture of the brilliant moon on the water in Fig. 31 is a scene that could not be duplicated on any other planet of the solar system.

The moon is the earth's nearest neighbor in space and shines by reflected light. It revolves around the earth in about a month and rotates on its axis in the same period of time. Conditions there are quite unfavorable for any form of life. The relationships of the earth, the moon, and the sun explain certain familiar happenings, among them eclipses, tides, and the moon's phases.

Can You Answer these Questions?

1. Why do we say that the moon shines by reflected light?

2. How long is a "day" on the moon? How long a period of daylight do you find there?

3. What evidence is there that no water or atmosphere is present on the moon?

4. Since the moon rotates, why do we not see more than one side of it?

5. What is the cause of the moon's phases?

6. What is the "earthlight" upon the moon?

7. What is the explanation of an eclipse of the sun? Why does an eclipse of the sun not occur more often?

8. What is the interval between low tide and high tide? Why should this interval be just that?

9. Is there any evidence that the moon affects the weather?

Questions for Discussion

1. Do any other places on the earth have as high a tide as the Bay of Fundy?

2. Does the moon exert stronger pull upon the water areas than upon the land areas of the earth? Why are there not tides upon the land — or are there?

3. Do you suppose there are craters on the other side of the moon, too? Why?

4. Which theory about the origin of the craters on the moon seems to you most reasonable? Why do you think so?

5. As you look at the mountains on the moon, you see they are very sharp and rugged. If you could look at the mountains on earth from afar, you would see that they are the opposite of this. Can you see any reason for this difference?

Here are Some Things You May Want to Do

1. Find out when the next total eclipse and the next partial eclipse of the sun will occur in your locality.

2. In Mark Twain's *A Connecticut Yankee at King Arthur's Court* you will find a humorous story of how the knowledge of a coming eclipse saved the hero from a lot of trouble. Read it. You may know of some similar stories. Tell the class about them. Perhaps you may want to write one of your own.

3. If you have ever seen an eclipse, write a story of your own observations. Perhaps you took some pictures of your own. Bring them to class and show them to the others there.

4. Set up a demonstration to show the relative motions of the sun, the earth, and the moon and one to show why the moon has phases.

5. Make a wall chart to show the relative positions of the sun, the moon, and the earth during a solar eclipse.

6. Read the account of the solar eclipse of August 31, 1932, in the *National Geographic Magazine* for September, 1932.

7. If you live near the ocean, make a study of tide-tables for the next month. Do you find that the time of low tide and high tide varies? Is there any relationship between these differences and changes in the moon?

Chapter V · How do the Earth's Motions affect Conditions upon the Earth?

A. Why do Changes occur in the Length of Day and Night?

As you read this unit on the earth's motions you will doubtless think of some of their effects upon conditions here. No one needs to tell you that daylight is due to the fact that the sun is shining upon our side of the earth, nor

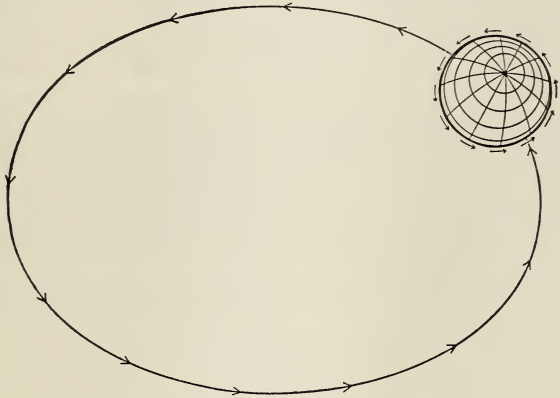


FIG. 44. The Earth has Two Important Motions

that night comes to us when our part of the earth is turned away from the sun. But perhaps you would have a little difficulty in explaining why the days in summer are so much longer than the days in winter here in the United States. Perhaps you could not tell why there is a Land of the Midnight Sun or a Land of Midday Darkness.

If you have a correct picture of the earth, you see it as a body nearly spherical in shape, that is, almost a ball. It has two motions, as illustrated in Fig. 44 : one a revolution around the sun in an orbit which is almost circular, and the

other a rotation on an imaginary axis passing through the poles. From a previous chapter you will remember that the earth's axis does not cross, or intersect, the plane of the earth's orbit at right angles. It is inclined, or tipped, from the vertical to an angle of $23\frac{1}{2}$ degrees. This fact is of great importance in explaining certain changes that occur upon the earth. Let us see why.

The axis of the earth is inclined at an angle of $23\frac{1}{2}$ degrees

This angle of $23\frac{1}{2}$ degrees is nearly the same at all times. If the earth's axis were extended out into space, it would pass near the North Star. Therefore this star is directly overhead at the north pole.

The northern end of the axis always points almost directly to the North Star

But the earth is sweeping around the sun in a large orbit. Obviously, then, at some time during the year the north pole is tipped toward the sun, and at some other time it is tipped away from the sun. The same is true of the south pole. Thus we have a condition in which places near the north pole receive more sunlight at one time during the year than they do at other times. Let us study a little more closely the conditions that are responsible for these changes, and how they affect life upon earth.

Turn back to Fig. 25. This shows the position of the earth in relation to the sun in March, June, September, and December. With a globe and a flash light you may study at close range the manner in which the earth is lighted. Fig. 45, *a*, shows the area of the earth's surface lighted on June 21. On this date the vertical rays of the sun are on the tropic of Cancer. The slanting rays extend beyond the north pole, and all of the arctic zone is in sunlight. Under these conditions the arctic zone is the Land of the Midnight Sun. At this time all of the antarctic zone is in darkness, for the sun's rays do not extend into it at all. On this date the sun can be seen at noon on the antarctic circle, but throughout the remainder of the twenty-four hours it is not visible.

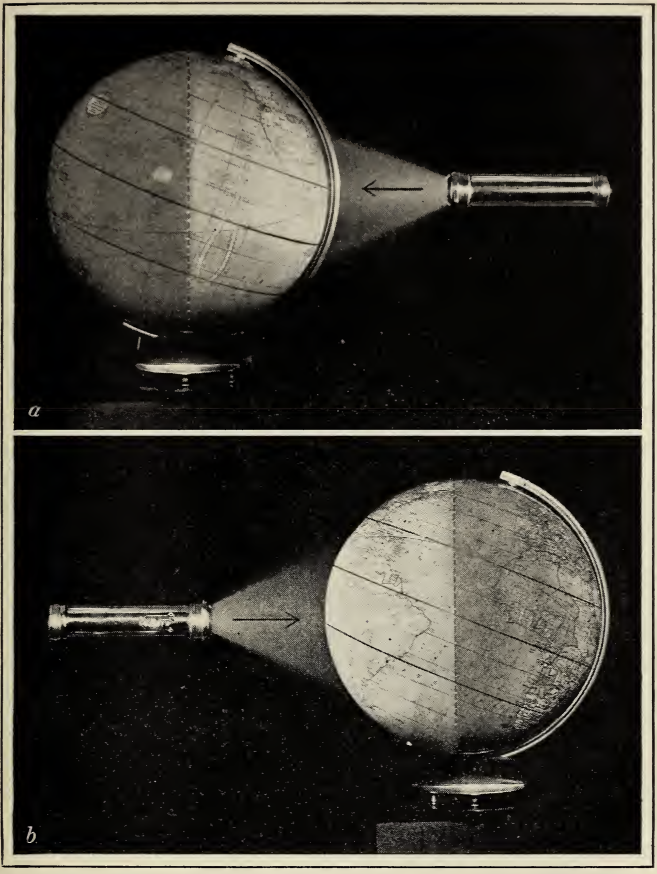


Fig. 45. Points near the North and South Poles receive More Sunlight at Some Times of the Year than at Others

In *a* are illustrated the conditions on June 21; in *b*, the conditions on December 21

The conditions illustrated in Fig. 45, *a*, are the conditions in which we, in the Northern Hemisphere, have summer. It is easy to see from this figure that more than half

of the earth's surface in the Northern Hemisphere is in daylight. If you could travel northward in June you would find the hour of sunrise earlier and earlier, and the hour of sunset later and later. Finally you would come within the arctic circle where the sun is above the horizon through twenty-four hours. This is the Land of the Midnight Sun.

As the earth revolves in its orbit, the length of the period of daylight changes

It is on June 21 that the vertical rays of the sun are farthest north. On this date they are over the tropic of Cancer, $23\frac{1}{2}$ degrees north of the equator. This date is called the summer solstice. Solstice means "standing still of the sun." The word is used because on this day the vertical rays stop moving northward and begin to move again toward the equator.

Fig. 45, *b*, shows conditions on December 21, at the time of the winter solstice. This is six months later. Now the vertical rays are over the tropic of Capricorn. On this date the region within the antarctic circle is in sunlight. The Southern Hemisphere is lighted on this date just as the Northern Hemisphere is lighted on June 21. In December the periods of daylight and darkness in southern Argentina are of the same length as in the United States in June. It is summer there while it is winter here. Through the winter months of the Northern Hemisphere the region within the antarctic circle is the Land of the Midnight Sun, and the region within the arctic circle is the Land of Midday Darkness.

Consider now the conditions which prevail when the earth is at two other positions in its orbit, as shown in Fig. 25. By September 21 the earth has moved so that its axis is inclined neither toward the sun nor away from it. Thus the rays of the sun fall as much upon one pole as upon the other. As a result all places in the world have twelve hours of daylight and twelve hours of darkness on September 21.

The same condition occurs again six months later, on March 21. These two days are called the autumn equinox and the spring equinox. The word *equinox* means "equal night."

You now have an explanation for the uneven and unequal hours of daylight and darkness in different parts of the world. If the earth were always in the position indicated for either March 21 or September 21, or if it were not inclined on its axis, you would always have a day with twelve hours of sunlight and twelve hours of darkness. Since this is not so, these hours of sunlight and darkness vary as the position of the earth changes. As the north pole tilts away from the sun, the hours of daylight grow shorter in the Northern Hemisphere and longer in the Southern Hemisphere. This is the condition from June 21 to December 21. As the north pole comes around to a position toward the sun, these conditions are reversed, and so we have our gradually lengthening hours of daylight from December 21 to June 21.

As the earth moves in its orbit around the sun, the vertical rays of the sun move back and forth between the tropic of Cancer and the tropic of Capricorn. As these rays move back and forth, the length of day and night changes, and the seasons come and go.

In the following table are given the times of sunrise and sunset at two points in the United States for certain days of a particular year.

Date	Charleston, South Carolina		St. Paul, Minnesota	
	Sun Rises	Sun Sets	Sun Rises	Sun Sets
March 21 . . .	6.03 A.M.	6.12 P.M.	6.01 A.M.	6.13 P.M.
June 21	4.52 A.M.	7.11 P.M.	4.12 A.M.	7.51 P.M.
September 21 . .	5.47 A.M.	5.59 P.M.	5.44 A.M.	6.01 P.M.
December 21 . .	6.58 A.M.	4.58 P.M.	7.35 A.M.	4.22 P.M.

See if you can answer these questions from a study of the table: On what date are the days longest? shortest?

In which city does the sun rise earlier and set later on each of the dates given? Which city has the longer period of sunlight in summer? in winter? Which city, the shorter?

There are more hours of daylight in summer than in winter

Along the fortieth parallel of north latitude the sun rises in December at about 7.30 A.M. and sets at 4.30 P.M. There is an interval of nine hours between sunrise and sunset, and of fifteen hours between sunset and sunrise. In the same latitude the sun rises in June at about 4.30 A.M. and sets at about 7.30 P.M. In June the interval between sunrise and sunset is about fifteen hours. There are, therefore, six hours more of sunlight in twenty-four hours in June than in December.

Notice that these statements are made with reference to points located on the fortieth parallel of north latitude. The times of sunrise and sunset at points located farther south or north would differ from those at the fortieth parallel.

At Seward, on the south shore of Alaska, you can see the setting sun on the horizon in June at ten o'clock at night. It appears again in the morning at about two o'clock. At this northern city, then, the day in June is one of about twenty hours of sunshine. In December the periods of darkness are about equal to the periods of daylight in June. The sun appears above the horizon at about ten o'clock in the morning, and it sets at about two o'clock in the afternoon.

Point Barrow, on the northern shore of Alaska, is in the Land of the Midnight Sun. In other words, it lies within the arctic circle. Here, in June, the sun remains above the horizon during the whole twenty-four hours. As the earth turns on its axis, the sun seems to move in a circle about this city of the Far North. It is highest above the horizon at twelve o'clock noon, and nearest the horizon at twelve o'clock midnight. It is noon when the sun is directly south of the city, and midnight when the sun is directly north of the city. The sun is never very high in the sky at Point

A. M. N. H.

Fig. 46. At Points within the Arctic and Antarctic Circles, the Sun sometime during the Year remains above the Horizon for Twenty-four Hours

This photograph, taken at Etah, Greenland, in July, shows the sun at various times during one day. The shutter of the camera was opened at twenty-minute intervals. Notice that the sun seems to be circling around the horizon

Barrow. Study Fig. 46. In winter at Point Barrow there are about forty days of darkness, during which the sun is continuously below the horizon.

The farther north you go the more hours of sunlight there are in summer and the fewer hours of sunlight there are in winter. At the pole there is the longest period of daylight in summer and the longest period of darkness in winter.

To the south of us here in the United States the days and nights are more nearly equal. At the equator they are just the same length at all seasons of the year. South of the equator the conditions are much the same as those north of the equator, except that when we have long periods of daylight in the north there are short periods of daylight in the south.

B. Why is Summer Hotter than Winter?

Along with the change in the length of day and night comes a change in temperature. As the days shorten, it gets colder; and as they lengthen, it gets warmer. Why is this? The earth is warmed by radiant energy from the sun. The sun's rays are not heat, as you probably know; for out in space where these rays are most intense, the cold is extreme. The sun's rays are changed into heat when they fall upon the earth. The fact that solar radiation is changed into heat may be illustrated by using a large reading glass. Focus, or concentrate, the sun's rays on a small area. Try focusing the rays on your hand. What do you feel? Focus the rays on a match. What happens? Or focus the rays on some tissue paper. What happens now? How can you explain these results? Are the rays hot? If so, the glass through which they pass should be hot. How do you explain the fact that it is not? Evidently something happens when the rays strike some object. In scientific terms, radiant energy is changed to heat when the rays fall upon a surface.

Temperature varies with the length of days

The amount of energy that comes from the sun has been measured. In Fig. 47 is shown a surface of one square foot held in such a way that the rays from the sun fall upon it vertically. Think of a ray as a straight line from the sun to the earth. The cardboard in Fig. 47 is held in such a way that this line is perpendicular to the surface. If none of the energy from the sun were lost in the atmosphere, the amount of heat from the radiant energy that falls upon this surface of one square foot in one minute would be sufficient to raise the temperature of one pint of water about 6.8 degrees (Fahrenheit scale). Heat from solar radiation warms the surface of the earth, and the heat on the surface warms the atmosphere.

The energy from a beam of sunlight of one square foot

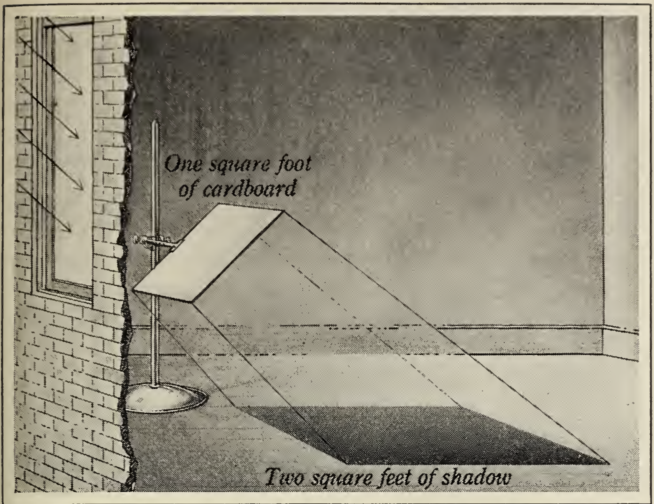


Fig. 47. The Energy of Sunlight spreads over a Larger Surface when the Rays are not Vertical to the Surface

in cross-sectional area spreads over a larger surface when the rays are not vertical to the surface. In Fig. 47 the rays strike the cardboard vertically, but they strike the floor at an angle. At the angle shown the shadow spreads over two square feet. On the floor, then, the energy is distributed over an area that is twice that of the cardboard. It follows, of course, that the amount of energy on the cardboard in Fig. 47 is twice as great as the amount of energy on one square foot of the floor. In other words, the sun's rays on the earth's surface, from the angle illustrated in Fig. 47, are only one half as intense as they are when the rays are vertical. Now apply what you have learned from your observation to actual conditions upon the earth.

The intensity of the heat from the sun at positions north or south of the equator is less than at the equator. It is true that at the latter point the sun is directly overhead on

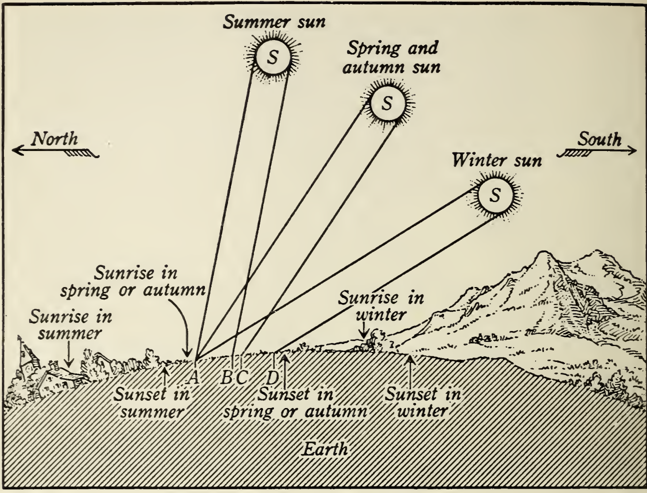


FIG. 48. As Rays of Sunlight strike the Earth at a Greater and Greater Angle, their Energy is spread over a Larger Area

Does this drawing help to explain why the hours of daylight are fewer in winter than in summer?

only two days of the year — March 21 and September 21. If you will consider the entire earth, however, you will see that the sun is more nearly directly overhead at the equator for a greater number of days during the year than at any other point on the surface of the earth. At your position in the United States the sun is never directly overhead. Study Fig. 48. This represents a section of the earth at about the fortieth parallel. Even at noon in the summer, when the sun is highest in the sky, it is always a little south of directly overhead. For this reason a beam of sunlight one foot square spreads over an area that is more than one square foot. Refer to Fig. 48 again. In the summer, with the sun almost overhead, a beam of sunlight may cover the area *A–B*. As the position of the sun changes, as shown for spring, autumn, and winter,

Heat is intense at the equator

the same beam of sunlight, while equal in width, covers a larger area. Contrast *A–B* with *A–C* and with *A–D*. You can conclude, then, that at all times of the year the heat of the sun at noon is less intense in the United States than in the torrid zone.

Another observation will help to make this point clear. Cut a piece of cardboard one foot square. At twelve o'clock, when the sun is highest in the sky, hold the cardboard so that the sun's rays fall vertically upon its surface. Notice the shadow of the cardboard on the floor. The area of the shadow on the floor is the area over which a band of sunlight one foot square spreads. With a piece of chalk draw a rectangle on the floor, marking the area covered by the shadow. If you measure this area, you will find that it is considerably more than one square foot. At the fortieth parallel the area covered by the shadow in December will be about two square feet. South of the fortieth parallel the area covered by the shadow will be less. North of the fortieth parallel the area will be greater. In June the area shaded by the cardboard is less than in December, for in June the sun is higher in the sky at noon than in December. The heat from the sun at noon on one square foot of the earth's surface in the United States is therefore greater in June than in December.

The rays of the sun are more nearly vertical in summer than in winter

In your study of day and night you learned that the days are longest in the Northern Hemisphere when the vertical rays are north of the equator. Now you have learned that the heat from the sun is most intense when the sun is most nearly overhead. These facts furnish the explanation for the heat of summer and the cold of winter. It is obvious that near the equator there is comparatively little difference in the intensity of the sun's rays from summer to winter. As one goes farther north or south from the equator, the differences become greater. These differences, of course, have a great effect upon life.

It frequently happens that some of our most northern cities in the United States have the hottest days in summer. Reports from the United States Weather Bureau show that the highest temperature ever recorded in Bismarck, North Dakota, is six degrees higher than the highest temperature ever recorded for Atlanta, Georgia, or New Orleans, Louisiana. Why is this? One reason why the heat is so intense in the North is that the period of sunshine is longer in the North than in the South. The interval from sunrise to sunset in July is about sixteen hours in Bismarck. At New Orleans this interval is about fourteen hours. If the length of the hours of sunlight were the only factor which determined temperature, one would expect to find the hottest temperatures in the most northerly parts of the world, where the sun sometimes shines for days at a time. Remember, however, that the angle of the sun's rays is another extremely important factor.

The length of the period of sunlight affects temperature

C. What causes the Seasons?

Perhaps the most important of all the events resulting from the shape and motions of the earth and its relationships to the other members of the solar system is that recurrence of changes called the seasons. Year after year they come and go, bringing to man very great changes in his environment. During these periods there are changes in temperature, in hours of daylight, in rainfall, in winds — in fact, in the health and energy of life itself.

Seasonal change has a tremendous influence upon life. This is especially true in temperate lands. Many types of industry are necessary to meet the demands created by colder or warmer weather. The habits of animals are influenced, as illustrated by the migrations of birds and other animals; plant life flourishes and then dies as the various

Seasonal changes have a tremendous effect on life

FIG. 49. Seasonal Changes affect the Activities of People

This is a typical summer scene in the temperate zone

seasons come and go. Even man himself is influenced strongly by changes in his environment. It is easy to find many familiar examples of man's ways of adjustment to these seasonal differences in the United States. In the spring the farmer prepares for the fall harvests by planting his seed. Later, when the seed has developed into a crop, he harvests it and stores the food necessary to maintain life during the winter. In the summer thousands of city dwellers flock to the mountains and to the country and to the seashore. As cooler weather approaches, the clothing dealers and the fuel merchants reach the peak of their season. So throughout the year different groups of people are busy, taking care of the demands made as a result of seasonal change. Seasonal sports are shown in Figs. 49 and 50.

What is the explanation of these changes? What are the factors which contribute to them? Let us recall what you already know.

FIG. 50. Winter Activities are Different from Summer Activities

Which activities do you like better, these or the ones in Fig. 49?

First, you have seen that vertical rays produce greater heat. From this it is easy to see that, as you move farther and farther on the surface of the earth away from the point of the direct vertical rays, the rays spread over a larger area and so do not produce as much heat.

Several factors contribute to seasonal change

Second, you know now that the hours of daylight in various parts of the world vary greatly as the earth revolves around the sun. It is quite natural to suppose that the region having longer hours of sunlight would be warmer.

You have just learned the cause for differences in the length of the periods of daylight and darkness. Can the seasons be explained in the same way?

Refer again to Fig. 25 on page 54. As the earth revolves in its orbit, the position of the vertical rays changes. As the vertical rays shift northward from the equator, the heat from the sun increases in intensity in the Northern Hemisphere. At the same time, the length of the day

increases. As the vertical rays shift southward, heat from the sun lessens in the Northern Hemisphere and the days grow shorter. As the earth turns, the vertical rays shift back and forth between the tropic of Cancer and the tropic of Capricorn. This causes the seasons to change.

The intensity of the sun's energy over a given region is changing continually. The greatest changes are in regions farthest from the equator. Over the equator changes are but little. The daily range of temperature within the torrid zone changes but little throughout the year. In the southern United States the lowest temperature of winter is about the temperature of freezing, and the highest temperature of summer is about 100° F. This is a range of about 70 degrees. In the northern United States the lowest temperature may be 40° below zero or lower, and the highest about 100° F. This is a range of about 140 degrees.

Obviously more of the sun's energy reaches the torrid zone in one year than reaches the temperate or the frigid zones. It is also obvious that more energy reaches the Northern Hemisphere during the interval from June to September than reaches the Southern Hemisphere during this same interval. Similarly, more reaches the Southern Hemisphere in the period from September to June than reaches the Northern Hemisphere.

On the earth, energy is distributed by winds and ocean currents. As you continue in your study you will learn how unequal heating causes air and water to flow over the earth's surface.

D. What determines the Boundaries of the Zones?

Suppose you were a schoolboy on Mars with a telescope as powerful as the best one now in use here. You would doubtless spend some of your time looking up into the heavens at your nearest neighbor among the planets. What you would call this body is only a guess, but its own inhabitants call it the earth.

Imagine now that you are a Martian looking at the earth through your powerful telescope. What might you expect to see under these conditions? Although it is nearer, you would find the earth less bright than Venus. It certainly would have a slightly different tint. If you knew as much science as the people on the earth do, you would guess that the earth's atmosphere is less dense than that of Venus. You would have reason to believe, too, that it contains less water vapor, for clouds reflect more light than do rocks or soil.

If you carried on your observations over a sufficient period of time, you would see white polar caps. The northern cap would be larger at one time of the year, while six months later the southern cap would be larger. You would notice land areas and water areas. There would be a broad band of green extending around the earth halfway between the poles. This band would always be green, but conditions north and south of it would change from time to time. As the snow melted about the northern polar cap, the land areas below it would take on a greenish tint until the green areas were spread over most of the land of the Northern Hemisphere. At the same time the snow about the south polar cap would extend farther and farther north, and ice would extend northward over the surrounding ocean.

Perhaps if your telescope were good enough, you would see on the land area barren desert regions in two parallel belts each about 15 or 20 degrees wide, one on each side of the green equatorial, or central, belt.

Suppose you sketched a map of the earth as you saw it through your telescope. What would it be like? Whether you chose the hemisphere containing North America and South America or the one containing Europe, Asia, Africa, and Australia, the colors would be the same: blue for the water; a brilliant green band covering about 45 degrees, across the land areas of the middle; a dark-red or orange

desert area on each side; another strip of green, less brilliant and changing from season to season, on each side of the desert areas, making two bands as wide as the green band at the middle; and a white cap at each pole.

As you looked at your finished map, you would see a globe rather definitely divided into bands, or zones. As a Martian you could not explain them any better than the people on the earth explain the appearance of Mars.

Now come back to the earth again. These color zones, or belts, have definite names in the science of weather and climate. When the scientist speaks of the north temperate zone, he has in mind a region with very definite boundaries resulting from the shape and motions of the earth. As a matter of fact the entire globe is divided into zones, or regions, all of which are determined by the same factors. Beginning at the north pole, these zones, or regions, are named the north frigid zone, the north temperate zone, the torrid zone, the south temperate zone, and the south frigid zone.

The boundaries of the zones are determined by the inclination of the axis of the earth

How are the boundaries of these zones determined? First, let us see what the boundaries really are. The north frigid zone extends from the north pole to a point $23\frac{1}{2}$ degrees south of the north pole, or to a point located at $66\frac{1}{2}$ degrees north latitude. Can you see any connection between this and what you know about the inclination of the earth's axis? You will remember that the earth's axis is inclined from the perpendicular to the earth's orbit at an angle of $23\frac{1}{2}$ degrees. When the earth's position in its orbit is such that the inclination is toward the sun (on or about June 21), the rays of the sun pass over the north pole and light the earth over a distance $23\frac{1}{2}$ degrees beyond the pole. The whole region north of the parallel at $23\frac{1}{2}$ degrees is lighted. This parallel is the arctic circle, and the region within the arctic circle is called the north frigid zone. The antarctic circle about the south pole is defined in a

similar manner. The region south of the antarctic circle, entirely lighted on or about December 21, is called the south frigid zone.

As you have learned, the vertical rays of the sun shift back and forth between two parallels. One of these is $23\frac{1}{2}$ degrees north latitude, the other $23\frac{1}{2}$ degrees south latitude. These parallels mark the boundaries of the torrid zone. The northern boundary is the tropic of Cancer, and the southern boundary is the tropic of Capricorn.

The temperate zones lie between the frigid zones and the torrid zone

The territory between the tropic of Cancer and the arctic circle is called the north temperate zone, and that between the tropic of Capricorn and the antarctic circle is called the south temperate zone. The former, then, is the territory within the boundaries of $23\frac{1}{2}$ degrees and $66\frac{1}{2}$ degrees north latitude, and the latter is the territory within the boundaries of $23\frac{1}{2}$ degrees and $66\frac{1}{2}$ degrees south latitude. The important thing to realize is that the boundaries of these zones are determined by facts regarding the shape and the motions of the earth.

E. What is the Nature of Seasonal Changes in the Different Zones?

Should you expect to find differences in the natural factors which make up the environment of these different zones? The answer is obvious, isn't it? You are already familiar with some of these differences. You probably know people who think of the frigid zones as lands of ice and snow, and of the torrid zone as a strip of hot country. Is this always true? Do you know any exceptions to this? What are some of the most important factors of the environment which are affected by seasonal change? In general, they are temperature, rainfall, and the hours of daylight. Each of these changes may be observed, and they seem to fit particular zones.

If you as a Martian had these facts about the zones, you could from your observation on Mars explain the observations you took a while ago.

In the temperate zones a fairly uniform rainfall is found all the year round. It may seem especially heavy in the spring and fall, but some form of precipitation is likely to come at any time of the year. While the hours of sunlight change in length during the year, these changes are not as great as might be expected. How about temperature? Is seasonal change in the temperate zones accompanied by changes in temperature? Recall cold winter days with the temperature sometimes below zero and the hot summer days with the temperature running well over 90° F. As you think of these illustrations, it seems fair to say that, in general, seasonal change in the temperate zone is marked by changes in temperature more than by any other factor.

Changes in temperature mark seasonal changes in the temperate zones

How about the torrid zone? Here the temperature is generally high. The sun is nearly overhead, and winters as we know them are unknown. Certainly there are no great changes in temperature to mark seasonal change in the torrid zone. Similarly there are but slight changes in the hours of sunlight. They are always nearly equal. Hours of sunlight, then, play no part in marking seasonal change in the tropical zone. How about rainfall? In some parts of the tropics it rains every day, and the rain begins at about the same time every day. It is sometimes jokingly said that watches might be set by the beginning of the rainy part of the day. While different parts of the torrid zone differ somewhat in their rainy seasons, it may be said that, in general, change in amount of rainfall is the factor which marks seasonal change in the tropics.

Changes in the amount of rainfall mark seasonal changes in the torrid zone

Finally let us consider the frigid zones. Rainfall plays very little part here. Temperature changes, however, are

very great. Although it is generally cold, it is much warmer in summer than in winter. At times during the year the sun plays over the territory within the arctic and antarctic circles for long hours. Nevertheless the rays are so slanting that they do not heat the land as they do points between the arctic and antarctic circles. How about the hours of sunlight? Think of the descriptions you have read of these parts of the world. If you will recall some of these as they tell of the Land of the Midnight Sun or of the Land of Midday Darkness, you will soon decide that changes in the hours of daylight are a striking feature of the frigid zones.

Changes in the hours of sunlight mark seasonal changes in the frigid zones

With all these facts in mind you may explain why the physical features of the zones would stand out clearly if the earth could be viewed from Mars with a sufficiently powerful telescope. From this position you could understand that the shape and motions of the earth determine the changes in the physical conditions on its surface.

In this chapter you have found a discussion of the seasons and of the climatic zones, of differences between summer and winter temperatures, and of changes in the length of day and night. All these things result from certain conditions. Let us summarize them for you.

1. The earth revolves around the sun.
2. The earth rotates on an axis.
3. This axis is inclined, or tipped, to an angle of $23\frac{1}{2}$ degrees from a line perpendicular to the plane of the earth's orbit. This angle is always the same.
4. As the earth revolves around the sun, the position at which the vertical rays of the sun strike the earth shifts back and forth between the tropic of Capricorn ($23\frac{1}{2}$ degrees south latitude) and the tropic of Cancer ($23\frac{1}{2}$ degrees north latitude).
5. In the Northern Hemisphere the days are longest and the heat is most intense when the vertical rays of the sun fall north of the equator. In the Southern Hemisphere

the days are longest and the heat from the sun is most intense when the vertical rays of the sun fall south of the equator.

6. The boundaries of the zones are fixed by the fact that the earth's axis is inclined and by the fact that the earth revolves around the sun.

Such conditions on the earth as day and night, differing temperatures, differences between winter and summer, seasons, and climatic zones are explained by the motion of the earth and its relation to the sun. The primary factors in this relationship are the rotation of the earth on an inclined axis and the revolution of the earth in an orbit around the sun.

Can You Answer these Questions?

1. In what ways does the inclination of the earth's axis at an angle of $23\frac{1}{2}$ degrees determine the physical conditions which influence life on earth?

2. Why are the dates of June 21 and December 21 called the summer and winter solstices? Why is September 21 called the fall equinox? Why is March 21 called the spring equinox?

3. What is the real explanation of the Land of the Midnight Sun and the Land of Midday Darkness?

4. Is there ever a time in the United States when the number of hours of daylight and the number of hours of darkness are exactly the same? If so, when? Why should this be so?

5. Why are the hours of daylight in the United States shorter in winter than in summer?

6. How does solar radiation heat the earth? What effects do slanting rays have upon this heating?

7. Is the sun ever directly overhead in the Land of the Midnight Sun?

8. What is the farthest distance from the equator that the sun may be observed directly overhead?

9. Why is it warmer, usually, on September 21 than on March 21 in the northern part of the United States?

10. On what date is the largest portion of the Northern Hemisphere in darkness?

11. In what part of the world does Christmas come in the summer time?

12. Why are the various boundaries of the zones located as they are? What determines the location of the tropic of Cancer, the tropic of Capricorn, the arctic circle, and the antarctic circle?

13. What are the main distinctive features of the various zones in terms of temperature, rainfall, and hours of daylight?

Questions for Discussion

1. A greenhouse is often quite warm, even though no artificial means of heating is in use. Can you explain the reason for this?

2. Upon a hillside sloping toward the south you will notice that even in midwinter the sun's rays seem warmer than they do on level ground. Why?

3. Is your father's business affected by changes in seasons? In what ways?

4. Does a modern airline transportation company need trained scientists in its organization? If so, for what?

5. What differences do you think might exist in the climate of the United States if the earth's axis were at a right angle to the plane of its orbit?

Here are Some Things You May Want to Do

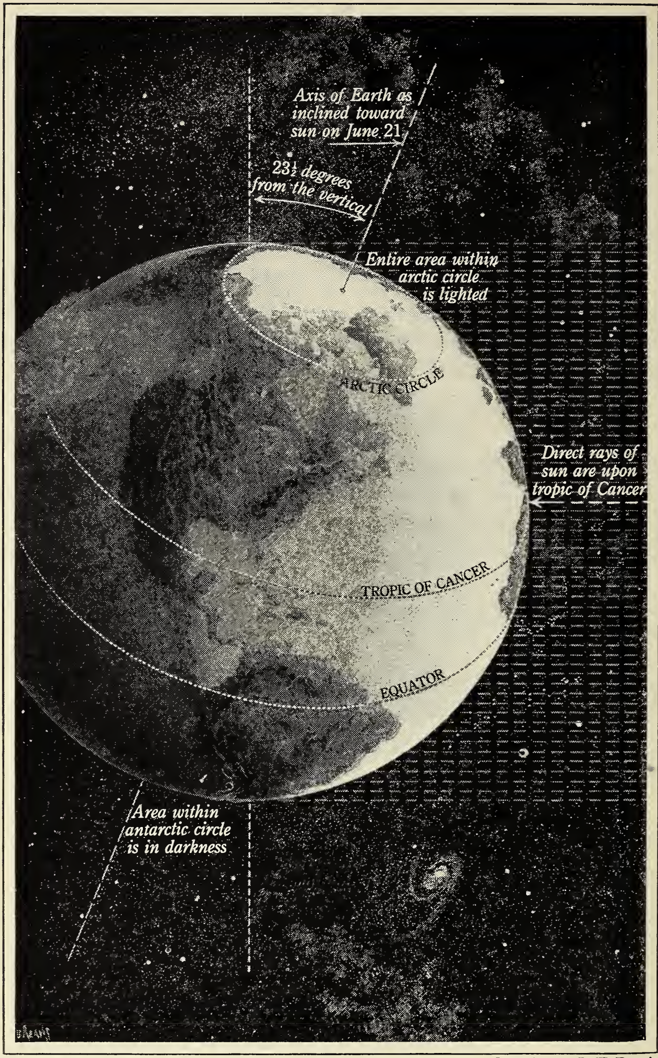
1. Make a graph showing the time of sunset each night for two months. Use an almanac to find the exact time. Do you find differences? Can you explain them?

2. Look in tonight's newspaper and see at what time the sun sets and at what time it will rise tomorrow morning. Confirm the time of sunset by actual observation. Keep track in this way for several weeks. Are there any differences between your record and that of your newspaper? What causes them?

3. Make a sundial for your own garden or for your school grounds. Where should you go for suggestions?

4. Some sunny Saturday or holiday lay out a sun clock in your back yard or in a vacant lot. Place a stick about six or eight feet long upright in the ground. At eight o'clock in the morning put a stone or some other marker where the shadow of the stick falls. Do the same at every hour until sunset. Do the shadows fall in the same places day after day? Is the clock accurate? Will it be accurate all the year round?

5. Read *Uncle Sam's Attic*, by Mary Lee Davis, or *Friendly Arctic*, by Stefansson. Note especially the description of the long summer days and the long winter nights, with their effects upon the inhabitants of the Far North.



Drawing by L. U. Reavis

FIG. 51. The Surface of the Earth is heated unevenly by the Sun. Heat is distributed by Winds and Ocean Currents

UNIT II

How may Different Climates and Changing Weather Conditions be Explained?

Chapter VI · What is the Explanation of Winds and Ocean Currents?

Chapter VII · What are the Differences between Our Climate and the Climates of Other Lands? What Conditions cause these Differences?

Chapter VIII · What is the Work of the Weather Bureau?

Chapter IX · What is the Character of the Weather of the Westerly-Wind Belt?

AS YOU watched the sunset in Chapter I and saw the stars move across the sky, you were reminded that the earth turns on an axis, making one complete rotation in twenty-four hours. You may have seen the sun mount higher and higher in the sky at noontime, and the days grow longer as summer approaches. As summer passes, you may have noticed that the elevation of the sun at noontime becomes less and less, and the days grow shorter.

As the seasons pass, you have been reminded that the earth revolves around the sun in an orbit that is nearly circular. Its axis of rotation is inclined at an angle of $23\frac{1}{2}$ degrees from a vertical to the plane of the path along which it moves. You have learned how these movements affect conditions on the earth.

In this unit you may learn something about the influence of such conditions upon your life.

Chapter VI · What is the Explanation of Winds and Ocean Currents?

A. What causes the Winds?

If you have ever read about the experiences of aviators who have flown across the Atlantic, you know that it is much easier to fly from North America to Europe than it is to fly in the opposite direction. All the flyers who have tried the westward trip tell of powerful head winds blowing toward them which made their flight a constant battle against difficult conditions. Those who have flown in the eastward direction, however, speak of powerful helping winds behind them, or, as they say, on their tail. If you will look up the figures for these Atlantic flights, you will find that the time required for the eastward crossing is much less than is needed for the westward crossing.

Similarly, more time is required to fly across the United States from east to west than is required to fly in the opposite direction. Again the aviators speak of favorable and unfavorable winds.

From these accounts and others it appears that there are certain regions, or belts, on the earth's surface, within which winds seem to blow in one direction. What explanation is there for this? Does the story of the earth and the solar system, as outlined in the first unit of this book, help to explain it? Let us see.

The energy that heats the earth comes to the earth in the sun's rays. Since the earth is a sphere, this energy is not distributed evenly over the earth's surface. Along the equator and near it the noon sun is almost overhead throughout the year. On this part of the earth's surface the sun's rays are most direct; and since this is so, as you have already seen, the heat which they produce is most intense. Near the poles the rays strike the earth at a sharp

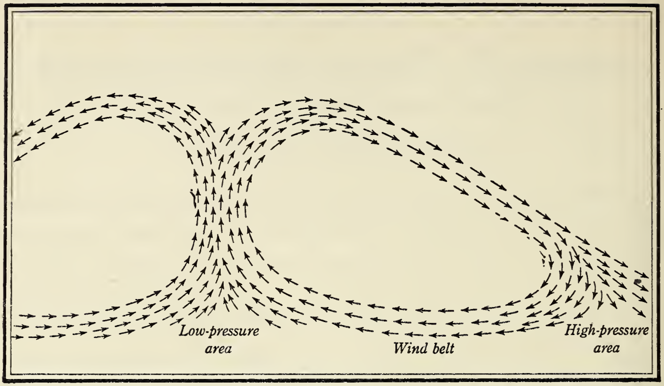


FIG. 52. As Air is warmed, it expands, becoming less Dense, and is forced up by Colder and Denser Air. Above the Earth it is cooled, and finally it descends again to the Surface

There is a region of low pressure where air is rising, and a region of high pressure where air is descending

angle, cover a larger area, and thus the heat they produce is less intense. From this it is evident that the atmosphere surrounding the earth is unevenly heated. You may see why this is so from Fig. 51.

Air currents are caused by an unequal heating of the earth's surface

The atmosphere in general is heated most intensely at the equator and least at the poles. On account of this uneven heating, convection currents are set up in the atmosphere just as they are set up in a heated room. The cold air is denser than the warm air and therefore exerts greater pressure, because the gravitational attraction for the cold, dense air is greater than the gravitational attraction for the warm and less-dense air. As a result of this greater pressure the cold air flows along the surface of the earth and forces the warm and less-dense air upward. There is an area of low pressure where less-dense air is being forced upward. There is an area of high pressure where dense air is descending. These are illustrated in Fig. 52.

With this introduction consider conditions as they are upon the earth as a result of its shape and motions.

As the earth moves in its orbit, the vertical rays of the sun shift back and forth across the torrid zone. Under the vertical rays the earth is heated most intensely, and at this position the air is least dense. Colder air comes in from the north and south, and the warm, less-dense air at or near the equator is forced upward by it. On account of the gravitational attraction of the earth this rising air cannot rise indefinitely. At higher altitudes it spreads outward as shown in Fig. 52. Some goes northward, some southward, to take the place of the colder air that is flowing toward the equator. High above the earth the air is cooled. As it cools, its density grows greater and so it slowly sinks again to the surface of the earth. This is a continuous cycle. Warmer air is pushed upward by colder air. After a time it descends again and moves over the surface of the earth. This air in motion on the earth, as shown in Fig. 53, is the wind.

There is a steady movement of air to and from the torrid zone

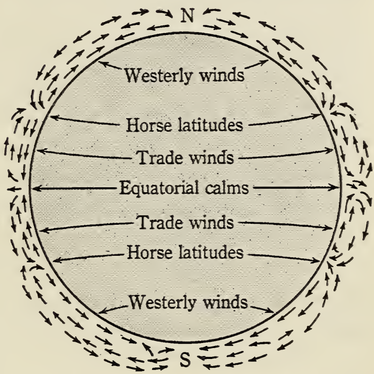


FIG. 53. As Air is alternately heated and cooled in Different Regions over the Surface of the Earth, the Movement is as represented Here

The arrows around the outside show the direction of the winds above the earth. The arrows upon the surface show the direction of the winds upon the earth

The less-dense air flows upward in the region of the equator, and the denser air comes in from the north and south. You might therefore expect the winds to blow directly from the north in the Northern Hemisphere and directly from the south in the Southern Hemisphere. This,

however, does not happen, as you can see by looking at the map in Fig. 55, which shows the principal wind belts of the world.

The map shows two belts of high pressure, known as the horse latitudes. In the Northern Hemisphere, between the horse latitudes and the equator, the winds on the earth's surface blow toward the equator from the northeast. In the Southern Hemisphere, between the horse latitudes and the equator, the winds blow toward the equator from the southeast. You might expect these winds to blow directly from the north in the Northern Hemisphere and directly from the south in the Southern Hemisphere, and so they would if the earth did not rotate on its axis. But it does, and this rotation deflects, or turns, the air currents in the torrid zone toward the west. Thus they become northeast and southeast winds; for north of the equator they blow from the northeast, and south of the equator they blow from the southeast. Notice that in both cases the air moves toward the equator, and notice also that as it moves toward the equator the direction is shifted toward the west, that is, it becomes an easterly wind. (See Fig. 54.)

Fig. 54. The North and South Direction of the Winds is changed by the Rotation of the Earth

Air currents are deflected by the rotation of the earth

These winds that blow on the surface toward the equator from the two regions of horse latitudes are called the trade winds. Where the trade winds from the northeast and from the southeast meet, the air is forced upward.

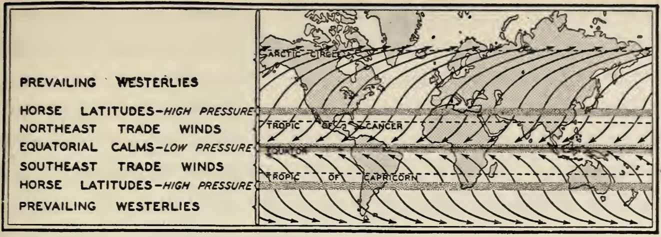


FIG. 55. This Map shows the Great Wind Belts of the World

Above the surface of the earth some of the air moves toward the north and some toward the south. There are, therefore, upper currents of air moving in directions opposite to the directions in which the trade winds blow. The upper currents are called anti-trade winds (*anti* means "opposite" or "against"). Fig. 52 will help you to understand the causes of the trade and anti-trade winds.

What conditions should you expect at the position where the air is moving upward? In the language of the sailor, this is the belt of equatorial calms, sometimes called the doldrums. Sailing vessels in this belt have great difficulty, for, since the air currents are upward, there are no winds to drive them. The "Rime of the Ancient Mariner" is a story of a sailing vessel in the belt of equatorial calms. The desperate condition is described in these words:

> Day after day, day after day,
> We stuck, nor breath nor motion;
> As idle as a painted ship
> Upon a painted ocean.

In Fig. 55 the belt of equatorial calms is shown on the equator. But it does not remain in a fixed position. This belt is in the region of most intense heat, and, as you have learned, this region is directly under the vertical rays of the sun. As the earth moves around its orbit the vertical rays move back and forth between the tropic of Cancer and the tropic of Capricorn. The belt of equatorial calms

moves north and south with the vertical rays. Physical conditions on the earth beneath the vertical rays change as the rays move along.

The torrid zone has two rainy seasons and two dry seasons

The belt of equatorial calms is a region of heavy rainfall. Do you see why? The air of the trade winds gets warmer as it moves in from the north and south to the belt of calms. Consequently these winds carry a great deal of water vapor. As the currents move upward the water vapor is cooled, and as a result some of the moisture condenses as rain. A season of rain therefore accompanies the passage of the vertical rays of the sun across the torrid zone. The rainy season is north of the equator from April to August. It is south of the equator from October to February, and it crosses the equator in March and September. During each year there are two rainy seasons and two dry seasons in the torrid zone.

The horse latitudes are regions of calm

The horse latitudes are regions in which the air of the anti-trade winds descends to the earth. These regions of descending air, like the regions of ascending air, are regions of calm. On the ocean this too is a region in which sailing vessels may have great difficulty. It is said that sailing vessels carrying horses have been caught in these calms. In order to save water and to lighten the ship the sailors have been forced to throw the animals overboard. This may explain why they are called "horse" latitudes.

These regions of descending air are regions of high pressure, and air flows out from these regions of high pressure toward the north and the south. The air moving toward the equator is the air of the trade winds. As you have learned, the rotation of the earth causes the trade winds to blow from the northeast in the Northern Hemisphere, and from the southeast in the Southern Hemisphere. Winds blowing toward the belt of equatorial calms are always turned toward the west.

Fig. 55 shows also air currents in which air flows toward the poles from the region of the horse latitudes. Notice that air moving toward the poles is turned toward the east. The winds north of the horse latitudes in the Northern Hemisphere are southwest winds, and those south of the horse latitudes in the Southern Hemisphere are northwest winds. These are the winds of the temperate zones, and they are described as westerly winds.

Most of the land surface of the earth is in the Northern Hemisphere. The land surfaces in the course of the westerly-wind belt cause many irregularities in the direction of the winds. In the Southern Hemisphere the westerly winds blow almost entirely over water. The southern portion of South America, a small section of southern Africa, the southern part of Australia, and a few islands are the only land areas in their course. The westerly winds of the Southern Hemisphere, however, are quite regular in their course.

The winds of the different belts have different effects upon the land areas near them

The horse latitudes, as you have seen, are regions at which the air of the anti-trades descends to the earth. Before the air is pushed upward at the equator, it is warm and carries a great deal of moisture. In the cold of the higher altitudes the moisture falls as rain, and when the air descends it is cool and dry. The air currents that blow from the horse latitudes toward the equator are dry winds. Since it is colder at high altitudes, these descending winds are cooler than the air at the surface of the earth. As the air is warmed, the amount of moisture which it can carry increases. The trade winds, therefore, gather moisture as they flow toward the region of equatorial calms. For this reason most of the great deserts in the world are in the path of the trade winds. In the Northern Hemisphere there are the Great American Desert, the Sahara, and the deserts of southeastern Asia. In the Southern Hemisphere there are the deserts of northern Chile, of southern Africa, and of central Australia.

B. What causes Ocean Currents?

If you have seen the effect of the wind sweeping across a lake and have watched it pile the waters into waves, you know that it can and often does affect large bodies of water. Consider the wind belts you have just studied and then compare Fig. 55, showing these wind belts, with Fig. 56, showing the principal ocean currents. Do you see any relationships? Notice from Fig. 56 that in the westerly-wind belt ocean currents move from west toward east. In the Northern Hemisphere these currents shift a little toward the north, while in the Southern Hemisphere the shift is toward the south. Along the equator the general direction of the equatorial currents under the influence of the trade winds is from east toward west. The winds seem to be the principal cause of ocean currents. The ocean currents are influenced, of course, by the land areas against which they flow.

Winds are one cause of ocean currents

In the Atlantic Ocean north of the equator there is the North Equatorial Current. This flow of water is driven along by the trade winds into the Gulf of Mexico. Since the land area of Central America blocks the westward flow, the water tends to pile up in the Gulf. The level of water in the Gulf is as much as three feet above the level of the Atlantic Ocean. Water flowing out of the Gulf of Mexico forms the Gulf Stream. Between Florida and Cuba the Gulf Stream flows with a speed of four or five miles per hour. The flow continues along the shore of the eastern United States and onward into the Atlantic Ocean in a northeasterly direction. The warm water, driven along by the westerly winds, flows toward the western shore of Europe and beyond the arctic circle, gradually cooling, of course, as it moves northward.

In the Pacific there is the Japan Current. This flows in the same general direction as the Gulf Stream, moving

Fig. 56. Is there any Relationship between the Great Ocean Currents of the World shown in this Map and the Wind Belts of the World as shown in Fig. 55?

from the warm region of the East Indian islands across the ocean toward the southern shore of Alaska.

There are other ocean currents, in which water flows from the north toward the south. Along the eastern shore of North America there is the Labrador Current. This is a current from the north. Partly owing to its influence the summers along the coast of New England are relatively cool, while Wisconsin and southern Minnesota in the same latitude suffer from extreme heat. The ocean water off eastern Maine is too cold for bathing, even in August.

There are warm and cold ocean currents

Where the Labrador Current and the Gulf Stream come near together, fogs are common. The Grand Bank, off Newfoundland, is a region of dense fog and severe storms that are well known to sailors of the Atlantic. Flyers crossing the Atlantic find this region very dangerous because of the fog. These fogs are formed as warm winds from the Gulf Stream to the south, carrying a large amount of water vapor, mix with the colder air over the colder waters of the Labrador Current.

There is an ocean current from the north that influences the eastern shore of Asia very much as the Labrador Current influences the eastern shore of North America. All these currents may be seen in Fig. 56.

C. How do Winds and Ocean Currents affect Climate?

The warm water from the Gulf of Mexico, driven by the westerly winds, flows toward the northeast. The wind, warmed by the water, in turn warms the western shores of Europe. London at 53 degrees north latitude is as far north as Hudson Bay and Labrador. Washington, D.C., at 38 degrees north latitude, is nearly a thousand miles nearer the equator than London is. Yet London seldom experiences cold as severe as that which frequently comes to Washington.

Another example may be given. In the north Pacific there is the Japan Current. The warm water from the east coast of Asia moves northeastward to the coast of Alaska. At Sitka, on the south shore of Alaska, the winters are mild, but over the mountains, only a few miles inland, the influence of the Japan Current is not felt and the winters are extremely severe. Perhaps your study of Fig. 56 and your knowledge of geography will help you to find other examples of these effects of winds and ocean currents.

An interesting way in which to study the effects of climate and other changing factors of the environment upon life would be to travel by airplane down the western shore and up the eastern shore of North and South America.

A few years ago an airplane flight of a hundred and fifty miles was a great achievement. Today one may travel by airplane from Seattle, Washington, southward along the western coast of North and South America, cross the equator, and go as far south as Santiago, Chile. This trip from 47 degrees north latitude to 34 degrees south latitude covers more than five thousand miles, beginning more than three thousand miles north of the equator and ending more than two thousand miles south of the equator. From Santiago the flight may be continued over the high peaks of the Andes Mountains to Buenos Aires, on the eastern coast of Argentina. Leaving Buenos Aires, one may fly back northward along the eastern coast of South America to Rio de Janeiro, to Recife, cross the equator again at Belém, go on to the Guianas, over the island of Cuba to Florida, and then from Florida across the continent again to the starting point at Seattle. Notice the extent of this flight as shown in Fig. 57.

Such a trip would be an exciting one. Think of the changing scenery: the air views of the Rockies and Andes, the thick tropical jungles, the vast regions of land and water! For a scientist, however, such a trip would have many interests beyond those of scenery alone. He would observe

FIG. 57. A Flight around North and South America reveals Many Differences in the Environment

The map shows conditions in January. Would wind direction and rainfall be different during other months of the year? Why?

Fairchild Aërial Surveys

FIG. 58. The Northwestern United States, in the Belt of the Westerlies, is a Region of Heavy Rainfall

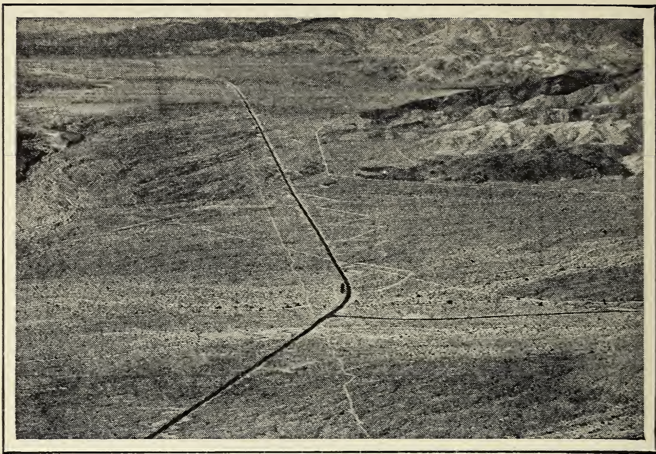
The picture shows Mt. St. Helens and Mt. Adams in the state of Washington. Notice the moisture and rich vegetation

the effects of wind belts and ocean currents on the conditions under which people along the path of the flight live.

Imagine that it is the month of January or February. The northern part of the United States is cold, for it is still winter there. From your reading and study, however, you know that south of the equator you will find summer.

Seattle, the point of departure, is in the belt of the westerlies. Mild winds, warmed by the Japan Current and with high humidity, blow in from the Pacific. Look at Fig. 58. As the winds move up the mountains on the west coast, they are cooled. This cooling causes precipitation, and so our journey is begun from a region of heavy rainfall. After a six-hour to ten-hour flight of over a thousand miles we reach southern California. Here we leave the belt of the westerlies and observe the influence of

The northern Pacific coast lies in the belt of the westerlies



Spence, L. A.

Fig. 59. Southern California is in the Belt of Deserts

This picture shows a portion of the desert near Los Angeles

the trade winds. These blow from the northeast, that is, from the land toward the ocean. Quite naturally this region is dry. The results of such air conditions may easily be shown by a comparison of these two regions. At Seattle the rainfall in one year varies from 0.6 inch in July to 5.6 inches in December. The range at Los Angeles, in southern California, is from zero in July to 3.1 inches in January. The total rainfall during one year in Los Angeles is about 15.2 inches, while at Seattle the total for one year is about 34 inches. In other words, the rainfall is more than twice as heavy in one city as in the other. Southern California is in the belt of deserts, the northern limit of which is marked by the horse latitudes. A portion of the desert is shown in Fig. 59.

We leave Los Angeles and continue our flight down the western coast into Mexico and Central America. This is still the region of the trade winds, and during the winter months it is a region of very little rain. The interval

FIG. 60. A Flight from the West to the East Coast of South America includes a Trip across the Andes Mountains

between November and May is the dry season of Mexico, for the vertical rays of the sun are south of the equator. Continuing southward over Central America and along the western coast of South America, we see how the influence of the eastern trade winds makes the region to the west of the mountains generally quite dry. The western shore of Colombia is a single exception, for here local conditions cause heavy rainfall throughout almost the whole year. Northern Chile, in the latitude of the southeast trade winds, is one of the driest regions in the world. Observations over a period of five years recorded a total of 0.6 inch of rain in the entire period.

Northern Chile has little rainfall

When we finally arrive at Santiago, we find we are about as far south of the equator as Los Angeles is north. Santiago is within the region of the southern horse latitudes. The rainfall there is about equal to the rainfall of Los Angeles. If we could continue from here to the region

Pan-American Airways

Fig. 61. The Pampa of Argentina is a Region of Rich Agricultural Land

south of the fortieth parallel, we should again be in the belt of the westerlies and we should find the southern part of Chile drenched with heavy rains. Santiago, however, is the southern terminal of the airways, and so we cannot see these conditions for ourselves on this imagined airplane trip.

Southern Chile has heavy rainfall

Our trip southward has been along the western coast of the continents. The region from Los Angeles to Santiago is mostly in the trade-wind belts. Since the winds blow from the east toward the west, they are from the land toward the ocean. The winds from the land are usually dry. So the western shore of the American continents from Los Angeles to Santiago is dry most of the way. North of Los Angeles and south of Santiago the winds are from the west, that is, from the ocean. In these regions the western coast of the Americas is wet.

From Santiago our plane starts across South America on its way to Buenos Aires. The flight is over the high mountains on the west coast, illustrated in Fig. 60, and across

Pan-American Airways

FIG. 62. Guiana, on the Northeastern Coast of South America, is a Region of Heavy Rainfall and Dense Vegetation

the plains of Argentina. This region too is in the trade-wind belt. As we move eastward the landscape changes from desert on the western slopes of the mountains to fertile valleys and productive lands from the central section to the eastern coast. The change in the landscape is similar to the change you would observe in traveling eastward from Denver to St. Louis in our own country. The Pampa, shown in Fig. 61, looks like Mid-Western farm country in the United States. This region of Argentina is one of the great wheat-growing sections of the world. The rainfall is sufficient for successful farming, being about equal to that of the great plains of the Mississippi Valley.

Some parts of Argentina have a moderate rainfall

In our trip northward across the torrid zone we shall travel along the eastern coast. Through much of the journey we shall experience heavy rainfall. To be sure, rainfall is heavier during the rainy season than during the dry season, but through most of the year there is considerable rain.

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FIG. 63. Florida has only a Moderate Rainfall

An airplane view of part of Miami

After leaving Buenos Aires we travel for six days, with stops along the way, mostly over Brazilian country. We learn that, in general, southern Brazil is in the region of heavy rainfall in January and the other summer months. At this time the equatorial calms are south of the equator, with the vertical rays of the sun, and the rising air currents cause heavy rainfall. The flight in January from Rio de Janeiro in southern Brazil for two thousand miles is for most of the way over flooded rivers and dense equatorial rain forests, as shown in Fig. 62.

Brazil has heavy rainfall

The flight from the Guianas over the West Indies to Florida is through the region of the northeast trades. We find the wind uniformly from the northeast. Florida has only moderate rains during this time, and the climate is mild and pleasant. Fig. 63 is a typical Florida coast scene. Continuing the trip northward toward New York, we are soon within the belt of the westerlies again. This is quite

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Fig. 64. The Rainfall on the Eastern Side of Central America is Heavy, as shown by this Scene of Panama Jungles

obvious, for in the westward flight from New York to Seattle we fly against the wind nearly all the way.

If this long trip along the shore lines of the continents were taken in June or July, conditions along the way would be somewhat different. The western coast of southern California, Mexico, and South America would still be dry along most of the way. The belt of calms, with the vertical rays of the sun, would now be over Central America, and during the summer months of the Northern Hemisphere these small states would be drenched with rain. June and July are the months of the rainy season in Central America and in central and eastern Mexico. The rains in central Mexico are, however, never so heavy as the rains of Central America. Notice Fig. 64. June and July are the months of the dry season in Brazil, and the rainfall in Brazil south of the equator during these months is about equal to the rainfall of the central Mississippi Valley. In northern Brazil and in the Guianas the rainfall is heavy all the year round.

In this excursion from the north temperate zone, across the torrid zone, into the south temperate zone, and back, the traveler is reminded again and again of the influence of the sun on the earth. As the earth moves in its orbit, the vertical rays shift north and south across the torrid zone. Along with the vertical rays of the sun move the belt of equatorial calms and the season of heavy rains. As the seasons change, the belts of the horse latitudes shift northward and southward. The change in seasons of the torrid zone is a change from a rainy season to a dry season. This change is caused by the northward and southward movement of the belt of calms.

Winds and ocean currents are the direct result of changes due to the shape and motions of the earth and resulting differences in the amount of the sun's energy received by the earth. These factors of the environment influence life upon the earth.

Can You Answer these Questions?

1. Why does it take longer to fly from Europe to North America than to fly in the opposite direction? Are the dangers greater in flying in one direction than in flying in the other? Why?

2. Why are the air currents of the earth deflected as they are in flowing north and south between the equator and the poles?

3. Where are the following regions located, and what is the explanation for each of them?

a. The trade-wind belts
b. The doldrums
c. The horse latitudes
d. The belts of prevailing westerlies

4. Why are the regions of heaviest rainfall in the torrid zone?

5. Why is it that most of the great deserts of the world are in the region of the horse latitudes and the trade winds?

6. Why are some ocean currents warm while others are cold?

7. What explanation is there for the constant fogs found off the coast of Newfoundland?

8. Why is it that London, which is almost a thousand miles farther north than Washington, D.C., seldom has as cold weather as Washington has in winter?

9. Why has the southern part of the Pacific coast less rainfall than the northern part?

10. Why does Brazil have heavy rainfall during January?

11. The airplane trip in this chapter was taken in January. What differences would have been found if it had been taken in June or July?

Questions for Discussion

1. Someone has said that if the earth rotated from east to west, America might have been discovered before the days of Columbus. What do you think?

2. Which do you think is the most important of the ocean currents in its effect upon civilization?

3. Do the winds of the trade-wind belt and of the belt of prevailing westerlies blow day after day in the same direction and with the same force?

4. From a map of the world's principal wind belts determine in what region of the world a sailing vessel could really be "blown around the earth" by the prevailing winds. Do you think this might be important to the future development of aviation?

Here are Some Things You May Want to Do

1. Today most of the world's ocean trade is carried on by steamships. Only a few sailing vessels are left. If you want to know about life on one of these, read Villiers's *Falmouth for Orders*. A similar account appears in the *National Geographic Magazine* for January, 1933.

2. A fine story of life in the sailing ship of days gone by is found in Dana's *Two Years before the Mast*. You may not want to read all of it, but some parts are very good. Read it and report on it in class.

3. What do you know about flights across the Atlantic? Who made the first one? Is the speed of the latest one very much faster than the speed of the first one? Where should you go to find out about these flights? What differences in speed are there between the eastward and the westward flights? You may want to prepare a class report, a booklet, or write a story entitled "How Airmen have conquered the Atlantic."

4. The airplane trip described in this chapter is over just one of the world's important air routes. You can, for example, fly by plane from England to South Africa or from England to the East Indies. Look up some of the other famous routes and see if you can describe a trip over them, as we have done in this chapter. It may help you if you indicate the routes on an outline map of the world.

5. On some afternoon or evening when the air is very still, build a small bonfire in some open lot. Throw some pieces of tissue paper into the fire and watch how the burnt remains rise into the air and the direction they take. Do your observations help to explain the conditions which cause air currents?

Chapter VII · What are the Differences between our Climate and the Climates of Other Lands? What Conditions cause these Differences?

A. What are the Climatic Conditions along the Amazon River?

In the high mountains of the small country of Ecuador, in western South America, are part of the headwaters of the Amazon River. *Ecuador,* in Spanish, means "the land of the equator." This country, until the days of air travel, was little known to white men, except for a small strip along the coast. Today explorers and scientists have traveled up from the western coast into the plateau country, over the high mountains and down the tributaries to the main stream of the Amazon River. From there they have gone through the jungles and rain forests down the Amazon to its mouth on the eastern coast of Brazil. Other explorers have traveled up the Amazon and its tributaries from Brazil to Ecuador.

You have already followed the flight of an airplane around the coast of South America. Now in imagination let us join a party of explorers as they travel by boat and on foot from the mountains of Ecuador through the Amazon Valley, following first a tributary stream as it rushes down the mountains and then the slow-moving Amazon through the rain forests to the Atlantic Ocean.

The Amazon River follows the equator

The Amazon flows from west to east in an almost straight course near the line of the equator, as you can see from Fig. 65. After we have traveled only a few hundred miles, the mountains are behind us and we have come to the main stream of the Amazon. From there onward, a distance of more than two thousand miles, the fall of the river is less than five hundred feet.

Throughout this journey we are near latitude 0 degree,

FIG. 65. The Amazon flows from West to East, paralleling the Equator

Can you find any evidence from this map as to whether altitude influences conditions along this river?

and the days and nights are always equal. There are no summer and no winter as you know these seasons, for the temperature does not change very much throughout the year. Suppose it is Christmas Day when your party sets out from Ecuador. At this time snow may be falling in Chicago and New York, and at four o'clock the streets in those northern cities must be lighted. It is at noon on Christmas Day that we take our first observation in Ecuador. The sun is not directly overhead, for its vertical rays are south over the tropic of Capricorn at about this time. It is, however, only $23\frac{1}{2}$ degrees south from the zenith, or highest point in the heavens, and it will not set until six o'clock.

We may start from Quito, the capital of Ecuador, which is near one of the head streams of the great river. In Quito the temperature from day to day varies little. There are, however, marked differences during the day. At night the temperature may be as low as 30° F., while at noon it may be as high as 75° F. In spite of this, however, records

FIG. 66. From Quito One may see Many High Mountain Peaks

show that over an entire year the average monthly temperature varies only between 54° and 55° F. So far as temperature is concerned, one day and one month are very much like every other one. No wonder Quito has been called the place of everlasting spring! From the city, located at an elevation of ten thousand feet, we may count over twenty mountain peaks towering far into the sky, some to a height of over twenty thousand feet. Such a view is seen in Fig. 66. Some of these peaks are volcanoes, but the tops of all of them are capped with snow that never melts. It is mountain snow, not winter snow, for the summits of these mountains are above the "snow line." During the rainy seasons it does not rain on these peaks. Instead it snows. Think of it! Snow at the equator all the year round! Land so cold no trees can grow upon it at latitude 0 degree!

Some lands of the equator have climates much like that of the United States

As we proceed eastward on our journey, we come to Indian villages, some of them a mile above sea level. These people live on the equator, but the climate of their country is not unlike that of our summers in the United States. Again, why should this be so in a land almost

FIG. 67. A Jungle is a Region of Heavy Vegetation

Contrast this scene with that in Fig. 68

directly on the equator? The Indian inhabitants cultivate the soil and grow crops which consist, among other things, of potatoes, squashes, corn, sweet potatoes, and tomatoes.

Traveling several hundred miles farther to the east,— beyond the plateau country, through a narrow strip of Peru, and down into the lower lands of Brazil, — we come to regions abundantly covered with vegetation. We begin to feel the damp, hot air so usual in the lowlands of the equator. Even though it is at present the dry season, we see that the "dry season" is not really dry. It is dry only in the sense that there is less rain during these months than during others. In these lowlands there are monkeys, innumerable snakes, and insects of great variety, with ants and mosquitoes everywhere. Water is abundant, and when the sky is not cloudy the sunlight is intense. Here grow rubber trees and other plants typical of the tropical jungle. A typical jungle scene is shown in Fig. 67.

Still farther to the east, where the river is wider and where the current moves slowly across the nearly level land, there are great stretches of equatorial rain forests. The rain forest differs from the jungle in several respects. Its trees are taller; its vegetation is thicker. It is hotter, damper, darker. Sunlight seldom reaches the ground through the dense leaves, and at the ground vegetation is not as heavy as it is in the jungle. Swamps and thickets hamper the explorer. Paths are covered with plant growth very soon after they are cut. No trails remain for long. Compare the environment in Fig. 67 with that in Fig. 68.

Jungle and rain forests are not the same

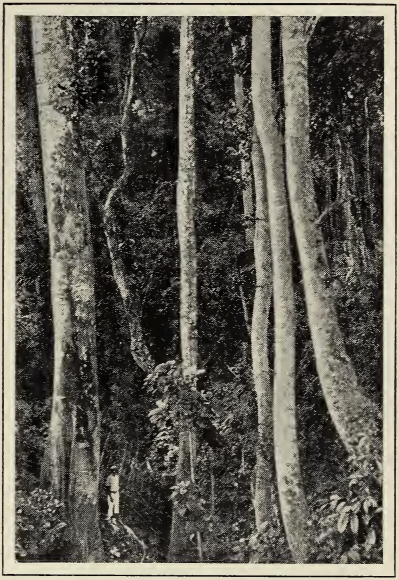


Fig. 68. A Rain Forest, as illustrated here, differs from a Jungle in Many Respects

What differences can you find between the scene here and the one in Fig. 67?

The journey down the river has been slow and dangerous. As time passes, the sun moves northward until in March it is directly overhead. We are now in the midst of the rainy season, and the river has swelled to a raging torrent. June finds us near the mouth of the river. The vertical rays of the sun are nearing the tropic of Cancer and the rainfall is not so heavy. After a long and difficult journey we reach the delta of the mighty Amazon. We have completed a journey along the equator from the Pacific to the Atlantic.

You have found temperatures changing very little from season to season. Records over longer periods of time are in agreement with your observations. In the following table are given the average monthly temperatures for Quito near one of the head streams of the Amazon and for Belém at its mouth. Locate these cities on the map in Fig. 65. Compare these figures with the ones given for Chicago. Notice the evenness of the average monthly temperatures along the equator and the great range of those at Chicago.

Points on the equator have even temperatures

Month	Quito	Belém	Chicago
	Degrees F.	*Degrees F.*	*Degrees F.*
January	54.5	77.7	24.0
February	55.0	77.0	25.5
March	54.5	77.5	34.9
April	54.5	77.7	46.2
May	54.7	78.4	56.6
June	55.0	78.3	66.5
July	54.9	78.1	72.3
August	54.9	78.3	71.2
September . . .	55.0	78.6	64.8
October	54.7	79.0	53.2
November . . .	54.3	79.7	39.2
December . . .	54.7	79.0	29.3
Yearly average . .	54.7	78.3	48.7
Range	0.7	2.7	48.3

You have seen the effect of altitude upon climate, for our journey began among snow-capped mountain peaks four miles high. You have experienced great differences in climate as you have traveled from Quito to Belém. You descended into an equatorial plateau country with a climate similar to that of summer in the Mississippi Valley. By contrast you came next to jungles and then to the typical equatorial rain forests, where there are few human inhabitants and where no white man can long remain, much less work.

White men cannot live in health and comfort in jungles and rain forests

FIG. 69. ALEXANDER VON HUMBOLDT, *One of the World's Great Travelers (1769–1859)*

THE two Von Humboldt boys, Wilhelm and Alexander, had every advantage that money could bring. Their parents were of noble birth and wealthy, and the boys had private tutors until they were ready to enter college in Berlin, their home town. When they completed their work at the university, each selected his own vocation. Wilhelm entered government service, but Alexander chose to see the world. Alexander had a keen interest in making collections and in keeping notes and diaries. He gratified these fancies on extended tours through America, into such regions as the upper Amazon and the newly opened lands west of the Appalachian Mountains. He made journeys through Russia and into Asia. He kept full and very accurate notes on these trips and later wrote them up, emphasizing the climate, the physical geography, and the plant and animal life in the countries he had visited. Among other things, he was the first to observe that meteoric showers occur regularly in November and on certain other dates. He coined the term *isothermal lines* in his descriptions of South American climate. He studied the phenomenon of the earth's magnetism and investigated the action of volcanoes. His fame is due chiefly to his *Kosmos*, a sort of encyclopedia of the natural resources of the whole world. It was based of course on the observations made during his tours of the world. Both Alexander and Wilhelm von Humboldt became famous in their chosen fields.

You observed the seasons of heaviest rains when the sun was overhead, and experienced dry seasons when the sun was north or south over the tropics. Perhaps the following table, giving rainfall in inches, will help to confirm your observations of rainfall.

Month	Quito	Belém	Chicago
	Inches	*Inches*	*Inches*
January	3.2	10.3	2.1
February	3.9	12.6	2.3
March	4.8	13.3	2.6
April	7.0	13.2	2.7
May	4.6	9.3	3.6
June	1.5	5.7	3.5
July	1.1	4.9	3.6
August	2.2	4.3	3.0
September . . .	2.6	3.2	3.1
October	3.9	2.5	2.4
November . . .	4.0	2.3	2.5
December . . .	3.6	5.1	2.1
Yearly total . . .	42.4	86.7	33.5

Can you find the rainy and dry seasons at the various points indicated? Notice that "dry months" in Belém generally have more rainfall than any month in Chicago. Can you explain why the rainfall is so much heavier in Belém than in Quito?

You found no strong winds, for you were in the belt of trade winds. You have experienced conditions in the belt of equatorial calms as it moved across the equator under the vertical rays of the sun.

There are no desert lands on the equator

You did not find any deserts. As a matter of fact, there are none on the equator in any part of the world. You did not experience the moderating effect of ocean breezes. You did not find long days and short nights, nor short days and long nights. You found a region where plant growth was abundant, but at the same time a region where human beings of the white race could hardly live.

B. What are the Climatic Conditions along the River Nile?

In Africa, as you can see from Fig. 70, there is the river Nile. Beginning in a lake almost on the equator, it flows for nearly four thousand miles northward to a point in the same latitude as Fort Worth, Texas. In its course it runs from almost 0 degree latitude to latitude 32 degrees north. Thus it reaches from the equator to a point about nine degrees beyond the tropic of Cancer and into the north temperate zone. What kind of life should you expect to find along such a river?

Fig. 70. The Direction of the Nile is from South to North

Does the difference in direction of flow help to explain why conditions along the Nile are not the same as those along the Amazon?

Its delta, in latitude 30 degrees north, covers more than a thousand square miles and is thickly settled. There is abundant grass, but few trees. Small farms produce crops in great quantities. There are a few rainy days in summer, but for the most part it is dry. The rich soil is made productive by irrigation. Numerous canals convey the water of the Nile to the farm land. Its climate is mild and warm. Such scenes as those in Fig. 71 are common. This region has been the home of highly civilized people since earliest history. Several cities, including Alexandria, Cairo, and ancient Memphis, have flourished on this delta.

The lands adjacent to the Nile delta are dependent upon irrigation

FIG. 71. The Nile Delta is a Region of Grassland Suitable for Agriculture

Would you say that this is a region of high civilization?

On each side of the river, beyond the few miles which are watered by irrigation, stretch vast deserts. To the west lies the great Sahara. To the east, across the Red Sea, the deserts reach beyond Africa into southern Asia.

You will remember that a short time ago you found from a map of the world that all the deserts of any size lie in two belts around the world, each of which is some twenty degrees wide. One is north of the equator on both sides of the tropic of Cancer. The other is south of the equator on both sides of the tropic of Capricorn.

The Sudan also experiences rainy and dry seasons

Farther up toward the source of the Nile the scenery is more nearly like that of the Amazon Valley. In the Sudan is a broad belt of grasslands inhabited by Arabs and Negroes. Here summer rains average from ten to twenty inches. Trees are there, but no dense forests. There is rain over the Sudan during the months from April to September be-

A. M. N. H.

FIG. 72. The Pygmies have become Adapted to their Environment

What evidences of adaptation can you find?

cause it is north of the equator, and during these months the sun is overhead. At this time the Sudan is in the belt of calms, where the warm air is forced upward by the trade winds blowing from the north and the south. In winter the Sudan is in the belt of trade winds blowing from northeast across the desert country. During this season there is little rain.

Africa too has definite regions of jungles and rain forests

Beyond the Sudan is the jungle country, the home of the large wild animals — the lion, elephant, leopard, giraffe, zebra, rhinoceros, and hippopotamus. There is abundance of rain when the sun is overhead. There is a short dry season when the sun is south of the equator. The jungles north of the equator are between the desert and the rain forests. In general you may find that the jungles bound the rain forests on the north and the south.

In the rain forests beyond the jungles dwell the Pygmies, the tiny black people whose photographs you may have seen in African travel pictures. Study Fig. 72. They have become adapted to the steaming moisture, to the insects, and to the constant heat which prevails day in and day out. They have become used to the frequent thundershowers. The dark floor of the rain forest makes a satisfactory setting for their pointed-roof houses, which protect them from the rain and to some extent from the heat.

The Nile flows over a distance of four thousand miles. All of this, of course, must be sloping toward the sea. Nevertheless its sources in the land around Lake Victoria are little more than three thousand feet above sea level. This fact explains why our journey up the Nile has not taken us into territory whose climate depends to a greater extent upon altitude. Some of the mountains in Ecuador, you remember, were four miles high and capped with snow. The land at the source of the Nile is covered with dense equatorial vegetation. The climate at the source of the Nile is the climate of a land area in the torrid zone at low altitude. The climate at the source of the Amazon is the climate of the torrid zone at high altitude. One is always warm; the other is a region of ice and snow.

C. Why does India have Three Seasons?

India, like the Mediterranean countries, is protected on the north by mountains — the lofty Himalayas. On the south there is the Indian Ocean. Northern India is crossed by the tropic of Cancer. Thus during the summer a large part of its territory is passed over by the vertical rays of the sun.

On account of the high mountains to the north the shifting of the vertical rays of the sun back and forth between the tropic of Cancer and the tropic of Capricorn exerts a peculiar influence on the climate of India. India, located

between latitude 10 degrees north and latitude 30 degrees north, is shown in Fig. 73.

In January, when the vertical rays of the sun are south of the equator, most of India is under the influence of the northeast trade winds. These blow from the snow-covered mountains and cold land surfaces lying to the north. As the wind moves southward it gets very much warmer. As the temperature of the air rises, it takes up moisture. This wind is a drying one; consequently there is very little rainfall in India during January, and the temperature is cool. For the month of January over a period of several years the average temperature for twenty-eight cities in India was 60.2° F.

The cool dry season continues until March. From March until June the vertical rays of the sun are shifting northward and on June 21 are over the tropic of Cancer in northern India. During this season the land surfaces, which warm much more rapidly than water surfaces, are intensely heated. The winds blow from the land, and the climate is extremely hot and dry. The average temperature in June for the same twenty-eight cities mentioned above was 84.6° F.

Fig. 73. India has Three Seasons

The upper map shows the direction of wind currents for January; the middle map, those for April; the lower one, those for July. Can you explain why these changes should result in the different seasons?

After June 21, while the vertical rays of the sun are north of the equator, the heat over central Asia continues. The intense heat causes the air to expand and become less dense. This in turn causes the winds to shift to the south and come in from over the Indian Ocean. Of course these are moist winds. In the interval from June to September much of India and Indo-China is drenched with rain. On the southern slopes of the Himalayas, where the air of the south winds is cooled as it is forced to higher elevations in passing up the mountain slopes, the rainfall is greater than at any other place in the world. In one year there may be about 500 inches of rainfall. As much as 40 inches of rain has fallen in one day.

India has a season of heavy rains

There are not many places in the United States where the rainfall during a whole year is as much as 40 inches. By way of comparison, the total rainfall in one year in Chicago is 33 inches, in San Francisco it is 29 inches, and in New York it is 43 inches.

As the vertical rays of the sun move southward toward the tropic of Capricorn, the land surfaces of central Asia north of the Himalayas get colder and the air over the land increases in density. By October these winds blow down over India again, and the cool dry weather begins. By January fires will be necessary for comfort in many parts of India. The extreme changes in temperature over the mountains and high plains of central Asia have a great influence on the climate of India, for these changes influence the direction from which the winds shall blow.

India, then, has three seasons: the cool dry, the hot dry, and the rainy. From October until March it is cool and there is but little rainfall. From March until June it is hot and extremely dry. From June until October is the season of heavy rainfall. The shift in position of the vertical rays of the sun and the change in temperature on the surface of the earth that accompanies this shift, influenced by the mountains and plains to the north and the ocean

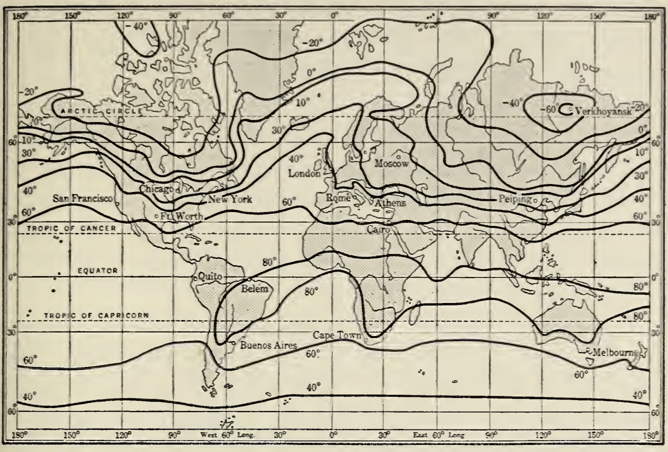


Fig. 74. Latitude Alone does not determine Temperature

The isotherms, or temperature lines, on this map indicate average world-wide temperatures for the month of January, as determined by long-time records. Which region is coldest? Which is warmest? Can you explain some of the differences shown?

to the south, cause these seasons. You will learn, as we continue our study of the changing earth, that there was a time in the distant past when there were no mountains to the north of India. At that time the climate of India was not the same as it is today.

D. Where is the Coldest Place in the World and Why is it so Cold?

The lowest temperature ever recorded out of doors was recorded in northern Siberia. On the map in Fig. 74 you may see that this region is far inland, away from the influence of the ocean, and just inside the arctic circle. During the long nights of winter this surface rapidly loses heat. Temperatures as low as $-90°$ F. have been recorded here. In summer the long days of sunshine warm

the region as rapidly as it cooled during the long nights of winter. On June 21 the sun remains above the horizon throughout the day. On this day this region in northern Siberia receives more heat from the sun in twenty-four hours than does a region of equal area in the torrid zone. This heat melts the snow and ice that formed during the winter, and during the summer months the temperature may be as high as 85° F., equal to a hot day in the United States. The extremes of temperature, from − 90° F. to 85° F., make a range of 175° F.

In northern Canada the conditions are similar, but the temperatures of winter are by no means so severe. One reason why it is less severe in northern Canada is that the land surface is not nearly so large. The moderating effects of the oceans protect the northern part of North America from such extreme cold. The average temperature in January is some twenty degrees higher on the arctic circle in North America than it is at the same latitude in northern Siberia.

It will be interesting to compare the climate of northern Siberia and northern North America with the climate of some islands off the western coast of Norway. All are at about the latitude of the arctic circle. The Norwegian islands are in the path of the warm Gulf Stream and are influenced by winds that blow from the ocean. The average temperature of these islands in January is about the same as the average temperature of St. Louis in January, and the extremes of temperature vary but little from the average. The average temperature of these islands during July is but twenty degrees higher than the January temperature. These islands illustrate in an extreme way the influence of water upon temperature. You must not decide, therefore, that all the regions in the north are cold. The slanting rays of the sun are an important factor in determining climate, but by no means the only one.

Not all northern regions are cold

The nearness of water seems to have an effect upon temperature. Why should this be? It is easy to show that soil may be heated more rapidly than water. Place 200 grams of ordinary soil in one beaker and 200 grams of water in another. Set a thermometer in the soil and watch it carefully while you heat the soil with a Bunsen burner. Note the time at which you start. Remove the thermometer as soon as the temperature reaches 100° centigrade. How long did it take? Now set the thermometer in the beaker of cold water, and when the thermometer registers the temperature of the water begin to heat the beaker. Continue heating until the water boils, or until the temperature reaches 100° centigrade. Which took the longer to heat? From your results it is obvious that more time and more heat are required to warm water than to warm soil. From this you can decide that an hour of sunshine on a soil surface will warm the soil to a higher temperature than the same hour of sunshine will warm a water surface. Similarly, the soil will cool much faster than water cools.

Soil heats more rapidly than water

E. What is the Range of Climatic Conditions on Earth?

Although there seems to be a wide variety of climates in the world, and although some of the climates of the distant past were unlike those of the same countries today, nevertheless these differences all fall within narrow limits.

The hottest places on earth are in the Sahara Desert and in the Great American Desert in Arizona. In these regions the highest temperatures ever recorded are in the neighborhood of 130° F. The coldest temperature ever recorded at the earth's surface was 90° below zero. This was in Siberia about two hundred miles from the mouth of the Lena River. The average temperature on the earth through the year is 60° F. But when these temperatures are compared with those of the sun's atmosphere and with those of the cold of

space among the stars, we find that their limits are very narrow indeed.

The range of temperature on earth is comparatively small

The diagram in Fig. 75 represents the range in temperature between the cold of outer space and the temperature of the sun. This is a range of about 11,500° F. For purposes of comparison some other temperatures have been indicated in this diagram. Notice the line indicating the temperature of molten iron (2880° F.), and the temperature of the electric furnace (6300° F.). The range between the extremes of heat and cold observed on earth (– 90° F. to 130° F.) is two hundred and twenty degrees. This is an extremely small part of the entire range.

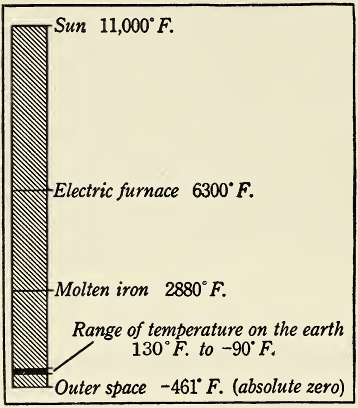


Fig. 75. The Range of Temperature on Earth is comparatively Slight

Happily for us and for other living things upon the earth, these limits of temperature on earth include the melting point of ice (or the freezing point of water), and the upper range is well below the boiling point of water. Water, therefore, is usually at hand in the liquid state. If this were not so, it is impossible to see how living things could exist at all.

These limits of temperature also guarantee that both carbon dioxide and oxygen will be gases. A world covered with "dry ice" or liquid oxygen could not be a living world.

Although the rainfall varies in different places from nearly five hundred inches per year to almost nothing, there are but few places in the world where it is too dry for anything to grow.

The shape and motions of the earth and the inclination

of its axis are major features influencing climate. But from your observations in the valleys of the Amazon and the Nile, on the plains of Siberia, on the islands of the north Atlantic, and other places you see that local conditions on the surface of the earth may produce very great effects. You may not take it for granted that all polar regions are cold and that all equatorial regions are hot. There are equatorial regions cold because of altitude, polar regions warm because of wind and ocean currents, and regions within the belt of deserts that are drenched by heavy rains because of mountain ranges. In these regions and in all others, physical conditions are effects which result from natural causes. In your study of this changing world you are seeking to understand these causes.

Climatic conditions depend upon temperature, moisture, and wind. All these factors combine in different relationships to create different climatic conditions. While these sometimes seem extreme, they are nevertheless within the limits which make life possible.

Can You Answer these Questions?

1. What is the explanation for snow-capped mountain peaks on the equator?

2. What differences are there between a jungle and a rain forest?

3. How do you explain the evenness of temperature on the equator?

4. Why are there no deserts on the equator?

5. What is the explanation for the so-called wet and dry seasons of the torrid zone?

6. Why should the climate of southern India differ from that of the Nile delta? Both of them are in about the same latitude, both are nearly at sea level, and both are near bodies of water.

7. Are the mountains at the source of the Nile River snow-covered? Why?

8. What effect have the oceans upon the temperature of near-by regions?

9. Why is the winter temperature of northern Siberia lower than that of northern Canada?

10. What regions in Europe are most affected by the Gulf Stream? What evidence can you give to support your answer?

11. Can you give any evidence to support this statement: "While the range of temperature upon the earth seems large, it is really very small when compared with the range of temperature in the entire universe"?

12. What are the four chief factors upon which the temperature of a region depends? What examples can you give of the effect of each of these?

Questions for Discussion

1. Do you think there is any region in the United States that might be called the Land of Everlasting Spring?

2. Should you like to live in a region where the temperature is even all the year round? What changes would there be in your way of living? Would such a life seem monotonous? What climate suits you best?

3. Civilization in the equatorial rain forests is on a very low level. What does this mean? Why is it so?

4. The range of temperature upon the earth is not far from 220° F. What do you think would be the effect upon life as we know it if the lowest temperature experienced upon earth was 220° F. below what it is now or if the highest temperature on earth was 220° F. above what it now is?

5. Egypt has a long and glorious past. Its civilization is one of the oldest on earth. How much of this do you think is the result of the rich agricultural conditions found in the Nile delta?

6. Some people believe that the course of the Gulf Stream is shifting from year to year. Have you any evidence in this chapter to show that this is or is not so?

Here are Some Things You May Want to Do

1. Look in your geographies or in an encyclopedia for other mountain ranges whose peaks, although well within the tropics, are always covered with snow. Check the location of these on an outline map of the world.

2. Write a story of your imaginary trip along the Amazon. Make it as interesting as you can by telling of the lives of the people, how they eat, how they dress, the kinds of plants and animals you see, and the like. Indicate how your habits must change to meet a changing environment.

3. A former president of the United States, Theodore Roosevelt, once explored the unknown region of the Amazon and discovered a new river, which he called the River of Doubt. It was later called Rio Téodoro and is now known as River Roosevelt. See if you can find his book *Through the Brazilian Wilderness* in your library. Read it and report on the life he found on his trip.

4. Many books have been written on the life of the ancient Egyptians along the Nile River. Look up some of these and read them. A very good account is given in Wells's *Outline of History.* Pay particular attention to how these people depended upon the Nile River floods for their agricultural prosperity.

5. Make a special study of the lives of the Pygmies in Africa and report to your class upon the ways in which these little people are adjusted to their environment.

6. See what you can find out about Verkhoyansk, Siberia, called the coldest place on earth.

7. Many careful studies have been made of temperature and rainfall in many parts of the world. A very complete record of such observations may be found in Kendrew's *Climates of the Continents.* If this book is in your school library or if you can get it from another library, look up these records for some of the places mentioned in this chapter. Make graphs of these records and see whether they agree with the statements made in this chapter. If you cannot get Kendrew's book, you may find similar figures in geographies and encyclopedias.

Chapter VIII · What is the Work of the Weather Bureau?

Have you ever read an old-fashioned medical almanac? Besides assuring you that the particular remedy it recommends is good for everything from corns to pneumonia, it usually has a weather forecast printed for the whole year. Ignorant people may follow the forecast, for they wish to think that they may plan their activities not only for a day but for a year ahead. But are such predictions reliable? Read some of them and see. For the northern part of the United States in December you may find a prediction such as this: "During the third week of the month there will be snow accompanied by low temperatures." For July you may read that certain weeks will have high temperatures, accompanied by thunderstorms. One does not need to know much about the weather to make predictions such as these, for cold is the common thing in the North in winter, and high temperatures with thunderstorms are common in July.

Long-time weather predictions are not reliable

The weather is a common topic of conversation, for there are always curiosity and uncertainty about what it will be tomorrow. There are many signs by means of which people predict the weather. Some of these have a true basis, but many have not. There is, for example, no evidence that it is more likely to storm during one phase of the moon than during another. If it happens to rain on Easter, there is no reason to think that it will rain for the next seven Sundays. There is no reason to think that fish will bite more freely before rain than at any other time. The "ground hog" may or may not see his shadow on "Ground-Hog Day" — it does not affect the weather. Neither does the heaviness of the fur on animals nor the

FIG. 76. The Simple Rain Ceremonies of Primitive Peoples are of No More Value than the More Elaborate Ones of the Professional "Rain-Maker"

heaviness of the husk on an ear of corn guide in any way in predicting the severity of winter. There are people in every community who will predict cold winters and hot summers, but there is no reason to believe that such predictions will come true. As you study the work of the Weather Bureau you will learn that predictions for more than a few days ahead are extremely uncertain.

The professional "rain-makers" also play upon the ignorance of people. Even in this day and age professional fakers are still to be found touring the country. They may resort to prayers and dances, they may use a lot of machinery, or they may walk about in a mysterious manner. But in any case their mumbo jumbo is of no more value than the simpler ceremonies of savage tribes (see Fig. 76). It is safe to decide that the performances of a man or group of men cannot in any way affect the weather.

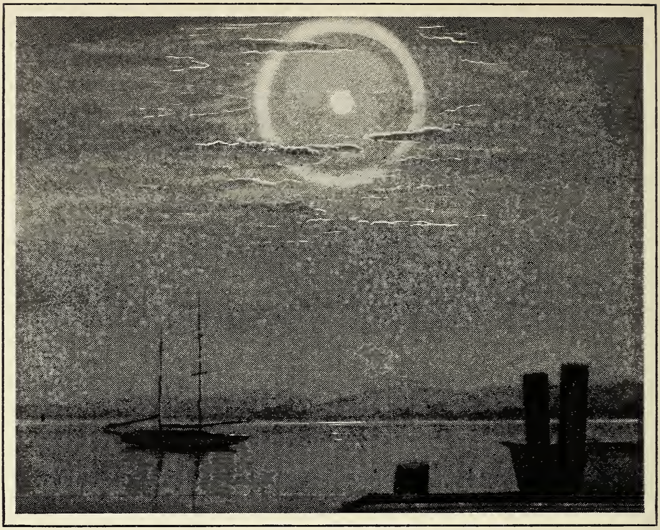


Fig. 77. **A Ring may be seen around the Moon when there is Mist in the Air**

This is an artist's drawing of such a ring

There are, though, some signs that have a real meaning. Have you read "The Wreck of the Hesperus," by Longfellow? There is a passage in this that reads as follows:

> Then up and spake an old Sailòr,
> Had sailed to the Spanish Main,
> "I pray thee, put into yonder port,
> For I fear a hurricane.
>
> "Last night, the moon had a golden ring,
> And to-night no moon we see!"
> The skipper, he blew a whiff from his pipe,
> And a scornful laugh laughed he.

A circle around the moon, as illustrated in Fig. 77, is frequently seen before a storm. The ring is evidence that moisture is condensing in little droplets. Under these conditions rain or snow may be expected.

When the sun sets clear, you may expect that the following day will be fair. When the sun sets behind a cloud, it is a sign that the next day may be stormy. These observations have real meaning; for since we live in a westerly-wind belt, it is likely that the weather conditions in the direction of the sunset will be the conditions which we shall experience before many hours. Do you see why?

Some weather sayings have a real basis

Here are some statements about the weather. Probably you can add many more. Which of these do you think have real meaning and which are merely superstitions?

1. Rainbow in morning, sailors take warning;
   Rainbow at night, sailors' delight.
2. If rain falls on St. Swithin's day, it will rain for the next forty days.
3. It always rains on the Fourth of July.
4. A dog eating grass is a sign of rain.
5. If it rains before seven, it will clear before eleven.

The weather forecast printed in the newspapers is much more dependable than any of the weather signs. At best the "signs" are based upon only a few observations, and probably these are taken carelessly. The official forecast is based upon many observations, all of which are taken with scientific accuracy. The Weather Bureau has a record for accuracy of about 90 per cent in its predictions. There are many jokes about the failures of the "weather man." He does fail occasionally, but often it is only in some minor thing. It seems easier, however, to remember the failures than to remember the successes. You may find it interesting to keep a record of successes and failures in the predictions of the Weather Bureau. In order to make this record, clip the weather forecast from the paper every day for a period of two or three weeks and paste the clippings in your notebook. Each day write after the clipping whether or not the forecast was correct.

The Weather Bureau forecasts are based upon scientific observations

A. Is there a Difference between Weather and Climate?

Often you find the climate of some particular region of the world described as rainy or hot or damp. On some occasions you may have complained about the rainy weather in your section of the country or the hot weather you have had for several weeks. Do these two words, *weather* and *climate,* mean the same? As you read this section, you will find that they do not. You will find, however, that there are some definite relationships between weather and climate.

The rotation of the earth on an axis that is inclined $23\frac{1}{2}$ degrees from a line perpendicular to the plane of its orbit, together with such physical features as mountain ranges, altitude, and nearness to bodies of water, determines the climate. As the seasons come and go, the climate of a region runs through a succession of changes. These changes are repeated year after year. We describe the climate of a region by describing the round of yearly changes in temperature, cloudiness, humidity, precipitation, wind direction, and wind velocity, or speed, as well as other factors.

Climate is average weather

Within this round of annual changes there are changes that come from day to day. In a region of heavy rainfall it does not rain every day, in a cold region it is not equally cold every day, and in a region of strong winds the winds do not blow with equal force every day. These changes that come from day to day are changes in the weather. Weather conditions through the seasons determine the climate.

As you know, the wind blows from a region in which the air is more dense toward a region in which the air is less dense. This wind may be a flow of cool or cold air, or it may be a flow of warm air. Cold air may be warmed as it moves along, as is the case when a wind from the north moves southward over the central section of North America and on to the Gulf of Mexico. In this case it is a dry wind; for, as the temperature rises, more and more water vapor

enters the air from the surface over which it flows. You may safely predict clear weather when you know that a cold current of air is moving southward and gradually warming as it flows along. You realize too that, as cold air is warmed, the region over which it flows is cooled. After a time the conditions which caused the north wind to blow have changed, and so the direction of the wind must change.

Warm air may be cooled as it flows along, as is the case when a warm wind from the Gulf of Mexico blows northward over the central states. Such a southeast wind is likely to bring rain; for, as the air is cooled, the water vapor carried with it condenses. You may safely predict cloudy weather and rain when you know that a current of warm air is moving northward and being cooled as it flows along.

B. What Instruments are used in Making Weather Observations?

The weather men (there are many of them) study the conditions that determine the weather; they find the humidity, the direction and velocity of the wind, the temperature, and other conditions. These weather men are located in stations distributed over the whole continent of North America. Look at the map, Fig. 78. Early every morning (8 A.M. Eastern standard time) their reports are sent to a few central stations. From these stations weather forecasts are made for periods ranging from thirty-six hours to a week. These are the forecasts you read in the daily papers.

If you have ever visited a station of the Weather Bureau, you may have seen some of the equipment that is used to study weather conditions. What scientific instruments are used by the weather men? Look at Fig. 79. In a station such as this you may see barometers for measuring air pressure, thermometers for measuring temperature,

Many instruments are used for weather observations

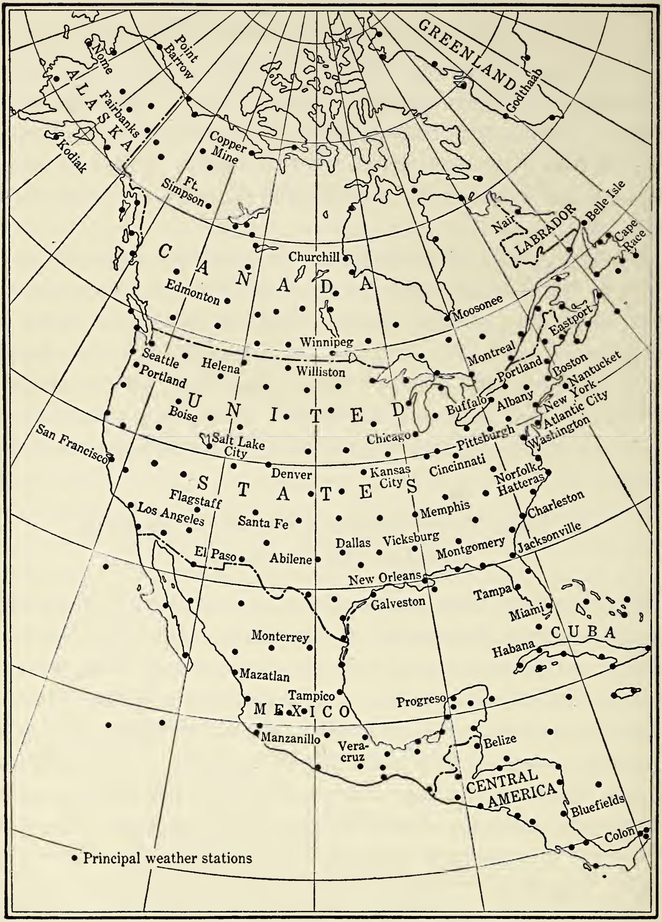
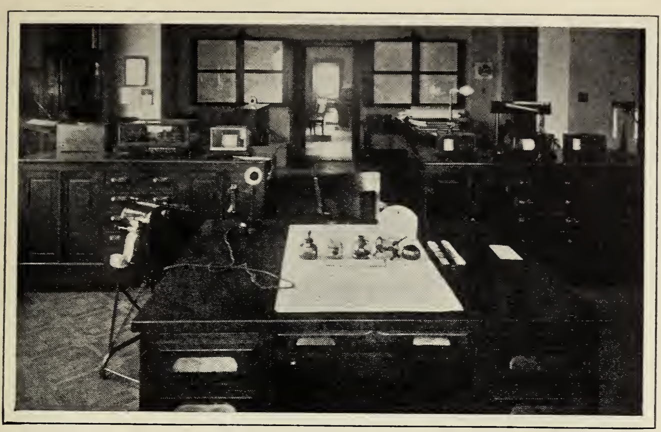


FIG. 78. **Accurate Weather Forecasts are made possible by Careful Study and Observation**

The map shows the principal Weather Bureau stations in North America. Notice that there are stations within the arctic circle. The stations indicated on the oceans are located on ships



U. S. Weather Bureau

Fig. 79. Weather Bureau Stations throughout the Country furnish Accurate Weather Forecasts

This is the station at New York City

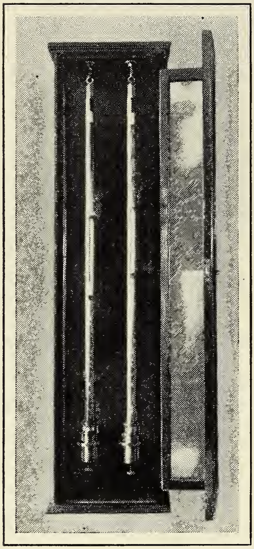
hygrometers for measuring humidity, instruments for measuring wind velocity and wind direction, instruments for recording the length of time the sunshine and clouds last, and possibly some others.

The standard form of barometer is shown in Fig. 80. It consists of a glass tube some 34 inches long which has been sealed at one end, filled with mercury, and turned upside down in a cup of mercury. Air pressure on the surface of the mercury in the cup prevents the mercury in the tube from running out. The height at which the mercury stands in the tube is a measure of air pressure.

A barometer measures air pressure

You may at some time have made a mercury barometer in your science laboratory. If so, you may wish to repeat the observations you made at that time. If not, you may want to construct such a barometer now. Secure a piece of glass tubing of the proper length (34 inches) and sealed at one end, a bottle of mercury, and a small dish to hold the mercury. Fill the

tube with mercury. Place your thumb firmly over the open end of the tube and turn it upside down in the dish of mercury. In doing this be careful not to allow air to enter the tube. You may fasten the tube in an upright position by means of a clamp fixed to a ring stand. What happens now? After the tube has been set in place, some of the mercury runs out until the force due to the downward pressure of the mercury just balances the force due to the pressure of the outside air. When you measure the height of the mercury column, you will find it a little less than 30 inches or, by the metric system, a little less than 76 centimeters. If you measure the height of the mercury on different days, you find that it is not always the same.



U. S. Weather Bureau

Fig. 80. A Barometer Measures Air Pressure

This pictures the standard mercury barometer used by the Weather Bureau. Why do you think two barometers are used?

Air pressure is about 15 pounds per square inch at sea level, but we commonly speak of air pressure as so many inches. When we say that the air pressure is 29 inches, we mean that the air pressure will support in a barometer a column of mercury that stands 29 inches high.

The barometer you have made is like the standard barometer at the station of the Weather Bureau, except that the one at the station is made and mounted with more care than you are able to use.

There is another type of barometer known as the aneroid barometer, illustrated in Fig. 82. This instrument is quite unlike the mercury barometer, but it is used for the

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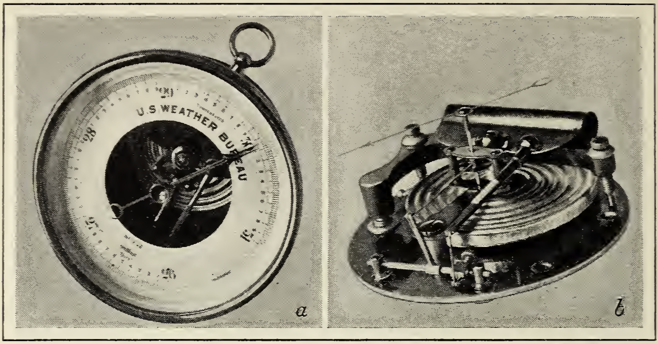
FIG. 81. BENJAMIN FRANKLIN, *Statesman, Editor, Inventor, and Scientist (1706–1790)*

THE name *Franklin* doubtless brings to your mind several outstanding pictures. You see the boy in his brother's printing office in Boston. You see the youth of seventeen entering the city of Philadelphia with a roll of bread under each arm and another partly eaten in his hand. Here is the young editor and printer working upon *Poor Richard's Almanac* in his own shop. And there is the man of leisure flying a kite during an electric storm. Here he is, prominent among the signers of the Declaration of Independence, and here again as diplomat in France borrowing money for our young republic. Franklin has been called our most all-round American. He was outstanding in government and in learning, but as a scientist alone he would have gained fame. His experiments with the kite proved, for the first time, that lightning is a discharge of electricity, a spark differing only in size from that between two charged objects. He invented the Franklin stove, a practical improvement over the open fireplace. He studied the course of storms, being the first to notice that a cyclonic storm generally reaches Philadelphia a full day before it reaches Boston, or, in other words, that "weather" usually proceeds from west to east across the United States. As a young man Franklin was a vegetarian, believing that we had no right to kill animals for food. But as he became older and observed that everywhere in nature life lives upon other life, he decided that his own beliefs made very little difference. After that he ate meat. (Illustration from a painting by Charles E. Mills)



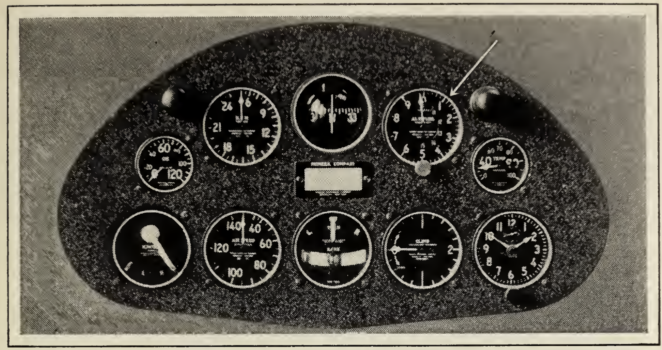
U. S. Weather Bureau

FIG. 82. An Aneroid Barometer also measures Air Pressure

a, barometer sealed; *b*, barometer with cover removed

same purpose. Inside the case of an aneroid there is a small metal box which has been tightly sealed after most of the air has been removed. In Fig. 82, *b*, the same instrument is shown as in Fig. 82, *a*, except that the cover has been removed. When air pressure increases, the sides of the box are pushed inward a little. When air pressure is lessened, the sides of the box bulge outward a little. The effect of these changes is carried to the pointer on the face of the barometer by means of levers. The pointer is mounted so that it moves toward the higher numbers on the dial when there is an increase in air pressure. It moves toward the lower numbers when there is a lowering, or decrease, in air pressure. The marks on the dial are made to correspond with the readings of a standard mercury barometer. When the mercury barometer reads 29 inches, the position of the pointer on the dial is marked 29. When the mercury barometer reads 30 inches, the position of the pointer on the dial is marked 30. The positions for the other figures on the dial are determined in the same way.

You may be surprised to know how easily affected an aneroid barometer is. It will show a difference between the



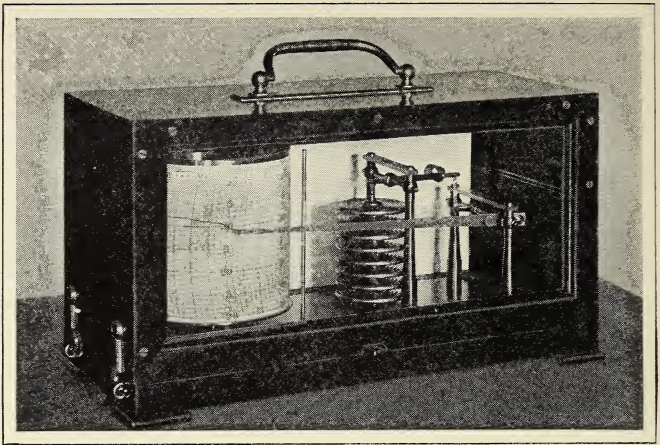
Aeronautical Chamber of Commerce, New York

FIG. 83. The Aneroid Barometer is Standard Equipment for Airplanes

The arrow points to the barometer as it is mounted on the instrument board

air pressure on the first floor of a building and on the second floor. Since air pressure becomes less as you climb upward, the barometer will read lower on the second floor than on the first. Air pressure at an elevation of 900 feet is about 1 inch less than air pressure at sea level. If the reading of the barometer is 30 inches at sea level, it will be about 29 inches at an elevation of 900 feet. While you are climbing 15 feet, the air pressure will change by $\frac{1}{60}$ inch. A good aneroid barometer will register even this small change.

The aneroid barometer is regular equipment for airplanes. Look at Fig. 83. The dial of the instrument on the instrument board is marked so that the aviator may read the altitude at which he is flying. At 10,000 feet, air pressure is about 20 inches. At 30,000 feet, air pressure is about 8 inches. Airplanes have flown as high as 8 miles, and at this altitude the aneroid shows that air pressure will support a column of mercury only 4.7 inches high. You may know, too, that aneroids are regular equipment for balloons that climb into the stratosphere, or upper portion of the atmosphere. In balloons altitudes of more than 12 miles have been reached. At a height of about 12 miles



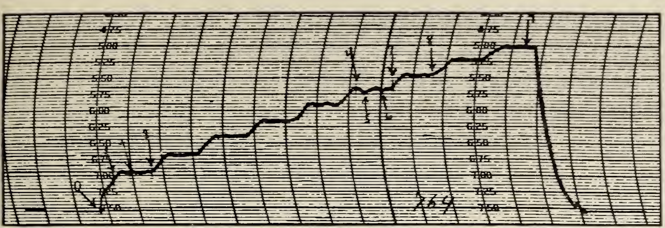
U. S. Weather Bureau

Fig. 84. A Barograph records Air Pressure

In this instrument a pen is fitted to an aneroid barometer

the aneroid shows a pressure equivalent to only 2.2 inches of mercury. Could you measure the height of a mountain by using a barometer?

There is one form of aneroid barometer known as a barograph. In this instrument, as you can see from Fig. 84, the little metal box is attached by levers to a pen. Another part of the instrument is a cylinder that is turned by clockwork. A piece of ruled paper is mounted on the cylinder. The pen moves upward and downward with changes of air pressure, and these changes are automatically recorded on the paper. Notice the record being made in Fig. 84. Other barograph recordings may be seen in Figs. 96 and 109. A striking example of the accuracy with which a barograph records changes in air pressure may be seen in Fig. 85. This is the barograph record of an altitude flight. At the left of the graph may be found the air pressure at the beginning of the flight. This is read as about 750 millimeters, which may be reduced to inches by multiplying



U. S. Weather Bureau

FIG. 85. The Record of an Altitude Flight shows clearly the Way in which a Barograph records Changes in Air Pressure

it by .03937. What was the air pressure on the ground? Notice how the air pressure lessened as the aviator reached greater and greater heights. What was the air pressure at the highest point of the flight? From a study of this graph, which should you say took longer, to climb or to come down?

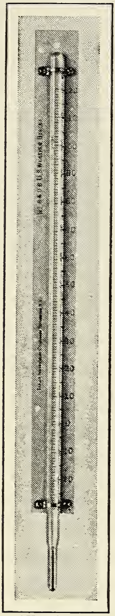
A barograph is carried on every altitude flight, but it is also regular equipment in the stations of the Weather Bureau for another purpose. The measurement of air pressure at different places furnishes an accurate basis for predicting the direction from which the winds will blow.

Different types of thermometers may also be seen at the stations of the Weather Bureau. The standard thermometer is like the one shown in Fig. 86. There is a tiny hole lengthwise through the stem, and a bulb filled with mercury is at the end. Mercury expands and contracts as it is heated and cooled. In making the thermometer, the end away from the bulb is left open and the mercury is heated until it just flows out through the open end. In this manner the air is forced out of the tube. The glass is then sealed by heating the open end of the tube in a flame until the glass melts.

A thermometer measures temperature

The tube with mercury in it is now placed in ice, and the position of the end of the mercury thread is scratched on the glass. This scratch is marked 0 for a centigrade thermometer or 32 for a Fahrenheit thermometer. Next, the tube is placed in boiling water, and the position of the end

of the thread is again scratched on the glass. This scratch is marked 100 for a centigrade thermometer or 212 for a Fahrenheit thermometer. The distance along the stem between these two scratches is now divided into 100 divisions for the centigrade scale and into 180 divisions for the Fahrenheit scale. Scratches to mark off equal divisions may be drawn below the freezing point and above the boiling point in order to register temperatures below the freezing point and above the boiling point of water. After the glass stem is marked in this way the thermometer is ready to use.



U. S. Weather Bureau

Fig. 86. This is the Standard Mercury Thermometer used by the Weather Bureau

Another type of thermometer is sometimes used. Inside the case of this second type there are two strips of metals riveted together and curved in the form of a semicircle. One of these strips may be composed of zinc and the other of steel. These metals, like mercury, expand when heated and contract when cooled, but zinc expands and contracts considerably more than steel. As the temperature rises, the greater expansion of the zinc increases the curvature of the bars. As the temperature falls, the greater contraction of the zinc decreases, or reduces, the curvature of the bars. This causes the end of the bar that is connected to the pointer to move; and as it moves, the pointer moves on the dial. The figures on the dial correspond to the figures on the stem of a standard mercury thermometer.

You may demonstrate the effects of change of temperature on such a "compound bar" by riveting together a strip of zinc and a strip of steel. Ask your science teacher to help you to do it. Use strips about one foot long. After

you have made the compound bar, hold it in a flame for a few minutes, and you may see that heat causes the bar to bend. The direction of the bend is such that the zinc is on the outside of the curve.

A metallic thermometer, that is, one made of metal, may be fitted with a pen which will record the temperature on a paper that is wrapped about a cylinder. Such an instrument is called a thermograph. It records the temperature in very much the same way as a barograph records air pressure. The equipment at the stations of the Weather Bureau includes both mercury thermometers and metallic thermometers.

The records of the Weather Bureau include also the humidity, or amount of moisture. The amount of water vapor that may be held in a given space depends upon the temperature. As the temperature is reduced, the amount of water vapor that may be held is reduced. There is always some water vapor in the air; and if the temperature is reduced sufficiently, some moisture will condense as dew.[1] The temperature at which moisture begins to condense from the air is the temperature at which the space is saturated. The amount of water vapor required to saturate the space at different temperatures has been determined and arranged in the form of a table. The table given on page 175 is taken from the reports of the United States Bureau of Standards. Notice that at a temperature of 0° F. a space is saturated with water vapor when it holds 0.481 grain of water vapor in each cubic foot. At 70° F. the

Humidity is a measure of moisture in the air

[1] In discussing humidity it is common to speak of air holding moisture as though the presence in a space of the gases of the air were essential to the existence of the water vapor. Strictly speaking this idea is wrong. Air contains water vapor in the same sense that air contains oxygen, but the presence or absence of air has no effect on the amount of water vapor that may be held in a space. It is merely the space that holds it. The temperature alone determines the amount of water vapor a space will contain.

saturated space will hold 7.98 grains in each cubic foot. Saturated space at 70° F., then, contains more than sixteen times as much water vapor as a saturated space at 0° F. contains. If the dew point of air is determined, that is, the temperature at which moisture begins to condense, the amount of water vapor in 1 cubic foot of air may be determined from the table.

You may determine the dew point of air in your schoolroom by cooling a glass of water with ice until dew forms on the glass. Keep a thermometer in the ice water. As soon as moisture appears on the outside of the glass, read the thermometer. Suppose you were to find that moisture forms when the temperature of the ice water is 40° F. From the table you may see that space is saturated with water at 40° F. when it contains 2.849 grains per cubic foot. You decide from this observation that the air in the room contains 2.849 grains of water in each cubic foot, or, in other words, that the absolute humidity of the air in the room is 2.849 grains per cubic foot.

It is important in weather forecasting to know how nearly saturated the air is. You may find the dew point to be 40° F. when the temperature of the room is 70° F. You may see from the table that air at 70° F. can contain 7.98 grains per cubic foot. If the dew point in your classroom is 40° F., it is obvious that the air of the room is not nearly saturated. You may state as a fraction the ratio between the amount of water vapor present and the amount that is required to saturate the air at the temperature of the room. In this case the fraction is $\frac{2.849}{7.980}$, which, stated as a percentage, is 35.5 per cent. In other words, the air in the room is 35.5 per cent saturated. *This percentage is called the relative humidity.* If the relative humidity out of doors is low, it is not likely that there will be rain. If the relative humidity is high, it is likely that it will rain. Do you see why?

WEIGHT IN GRAINS OF WATER VAPOR PER CUBIC FOOT WHEN AIR IS COMPLETELY SATURATED[1]

Temp., °F.	Grains	Temp., °F.	Grains	Temp., °F.	Grains	Temp., °F.	Grains	Temp., °F.	Grains
0	0.481	20	1.235	40	2.849	60	5.745	80	10.934
1	0.505	21	1.294	41	2.955	61	5.941	81	11.275
2	0.529	22	1.355	42	3.064	62	6.142	82	11.626
3	0.554	23	1.418	43	3.177	63	6.349	83	11.987
4	0.582	24	1.483	44	3.294	64	6.563	84	12.356
5	0.610	25	1.551	45	3.414	65	6.782	85	12.736
6	0.639	26	1.623	46	3.539	66	7.009	86	13.127
7	0.671	27	1.697	47	3.667	67	7.241	87	13.526
8	0.704	28	1.773	48	3.800	68	7.480	88	13.937
9	0.739	29	1.853	49	3.936	69	7.726	89	14.359
10	0.776	30	1.935	50	4.076	70	7.980	90	14.790
11	0.816	31	2.022	51	4.222	71	8.240	91	15.234
12	0.856	32	2.113	52	4.372	72	8.508	92	15.689
13	0.898	33	2.194	53	4.526	73	8.782	93	16.155
14	0.941	34	2.279	54	4.685	74	9.066	94	16.634
15	0.986	35	2.366	55	4.849	75	9.356	95	17.124
16	1.032	36	2.457	56	5.016	76	9.655	96	17.626
17	1.080	37	2.550	57	5.191	77	9.962	97	18.142
18	1.128	38	2.646	58	5.370	78	10.277	98	18.671
19	1.181	39	2.746	59	5.555	79	10.601	99	19.212

A wet-bulb thermometer measures humidity

A most useful instrument for determining humidity is the wet-bulb thermometer. In order to understand the principle of this instrument it may be necessary to review what you have learned about evaporation. The rate at which water evaporates is influenced by the humidity. If the humidity is 100 per cent, that is, if the space is saturated, water will condense from the air just as fast as water vapor passes into the air. The explanation of evaporation, as you may know, is that molecules of water are continuously moving and that some molecules are continuously entering

[1] The grain is the unit of weight used in humidity tables of the Bureau of Standards. It is a very small unit; 7000 grains make one pound. At one time grains of wheat were used as measures of weight. This unit was taken as the average weight of a grain of wheat.

the air from the surface of the water. If the air is saturated, it cannot contain more molecules of water; so molecules of water must leave the air by condensation, that is, they must condense from the air, as rapidly as they enter by evaporation. Suppose you could see the molecules of water over a surface of water in a vessel that is exposed to saturated air. Molecules would be entering the air by evaporation, but an equal number would be leaving the air by condensation. In this case the amount of water in the vessel and the amount of water vapor in the air would remain the same. In saturated air, then, the rate of evaporation and the rate of condensation are the same.

You may have learned that heat is the energy of moving molecules. As molecules pass from a liquid into the air, heat is carried from the liquid into the air. The surface from which evaporation is taking place is cooled by the process. If the air is saturated so that condensation and evaporation go on at the same rate, neither the temperature of the air nor the temperature of the water changes. If the air is not saturated, evaporation goes on more rapidly than does condensation, and the surface from which the water evaporates is cooled. If the relative humidity is low, the rate of evaporation is faster than when the humidity is higher, and consequently the cooling at the surface from which evaporation is going on is more rapid. With these facts in mind you may understand how the wet-bulb thermometer is used to measure humidity.

A common form of wet-and-dry-bulb thermometer is shown in Fig. 87. The cloth about the bulb of one of the thermometers is kept wet. The bulb of the other thermometer is dry, and the temperature by this thermometer is the temperature of the surrounding air. Suppose you take this instrument out of doors when it is raining, that is, when the air is saturated. The reading of the wet-bulb thermometer and of the dry-bulb thermometer will be

the same, because the humidity of the air is 100 per cent. But suppose you take it out when the air is clear. The reading by the wet-bulb thermometer will be lower, and the difference in the reading of the two thermometers shows how nearly saturated the air is. In other words, the difference in the reading of these two thermometers furnishes a basis for determining the relative humidity.

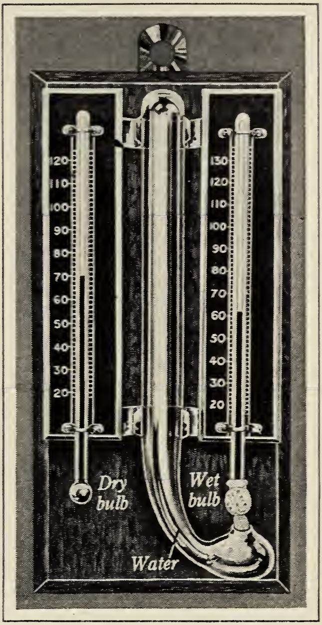


FIG. 87. A Wet-and-Dry-Bulb Thermometer may be used to determine Humidity

There is a constant relationship between the relative humidity and the difference between the reading of the wet-bulb and dry-bulb thermometers. This relationship has been found. It is given in the table on page 178. In one experiment to find the relative humidity the temperature of the room (the reading of the dry-bulb thermometer) was 70° F. and the reading of the wet-bulb thermometer was 62° F. In this case the difference between the readings of the two thermometers was 8°. The table shows that in this condition the relative humidity is 64 per cent. These are the conditions of a pleasant day.

A most convenient form of hygrometer, the instrument for measuring the amount of moisture in the air, is one with which the relative humidity may be taken by direct reading. It has been found that the length of hair is affected by changes in humidity. The hair lengthens when the humidity is low and shortens when humidity is high.

RELATIVE HUMIDITY, PER CENT. — FAHRENHEIT TEMPERATURES

Dry-Bulb Temp.	Difference between Dry-Bulb and Wet-Bulb Temperatures																	
	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0
60	94	89	84	78	73	68	63	58	53	49	44	40	35	31	27	22	18	14
61	94	89	84	79	74	68	64	59	54	50	45	40	36	32	28	24	20	16
62	94	89	84	79	74	69	64	60	55	50	46	41	37	33	29	25	21	17
63	95	90	84	79	74	70	65	60	56	51	47	42	38	34	30	26	22	18
64	95	90	85	79	75	70	66	61	56	52	48	43	39	35	31	27	23	20
65	95	90	85	80	75	70	66	62	57	53	48	44	40	36	32	28	25	21
66	95	90	85	80	76	71	66	62	58	53	49	45	41	37	33	29	26	22
67	95	90	85	80	76	71	67	62	58	54	50	46	42	38	34	30	27	23
68	95	90	85	81	76	72	67	63	59	55	51	47	43	39	35	31	28	24
69	95	90	86	81	77	72	68	64	59	55	51	47	44	40	36	32	29	25
70	95	90	86	81	77	72	68	64	60	56	52	48	44	40	37	33	30	26
71	95	90	86	82	77	73	69	64	60	56	53	49	45	41	38	34	31	27
72	95	91	86	82	78	73	69	65	61	57	53	49	46	42	39	35	32	28
73	95	91	86	82	78	73	69	65	61	58	54	50	46	43	40	36	33	29
74	95	91	86	82	78	74	70	66	62	58	54	51	47	44	40	37	34	30
75	96	91	87	82	78	74	70	66	63	59	55	51	48	44	41	38	34	31
76	96	91	87	83	78	74	70	67	63	59	55	52	48	45	42	38	35	32
77	96	91	87	83	79	75	71	67	63	60	56	52	49	46	42	39	36	33
78	96	91	87	83	79	75	71	67	64	60	57	53	50	46	43	40	37	34
79	96	91	87	83	79	75	71	68	64	60	57	54	50	47	44	41	37	34
80	96	91	87	83	79	76	72	68	64	61	57	54	51	47	44	41	38	35

Persons with curly hair are well aware of this effect, for their hair is more curly when the humidity is high than when it is low. The shortening of the hair under the influence of high humidity causes it to curl. A direct-reading hygrometer, such as shown in Fig. 88, may be made by fixing one end of a piece of hair firmly to a support and the other end to a rubber binder or to a metal spring, which is in turn fastened to a support. The end attached to the spring may also be attached to a pointer that moves over a dial. With increasing humidity the hair shortens and causes the pointer to move. The figures on the dial tell the relative humidity.

U. S. Weather Bureau

Fig. 88. Relative Humidity is indicated on a Direct-Reading Hygrometer

Fig. 89. As the Cups are turned by the Wind, Wind Velocity is recorded by the Gauge

The direct-reading hygrometer is a convenient form to use, but the results from its use are not as accurate as those obtained by either the dew-point method or the wet-bulb method.

A wind-gauge measures wind velocity

The instrument for determining wind velocity, or speed, is sometimes called a wind gauge. One is pictured in Fig. 89. The greater the velocity of the wind the faster the gauge turns. At the office of the Weather Bureau this gauge is attached to an electrical instrument which automatically records the wind velocity. The direction from which the wind blows is also recorded automatically. The bureau has a continuous record of wind velocity and wind direction.

The predictions of the Weather Bureau are based upon careful observations of the conditions of the air. Observations are made with the best instruments obtainable. These observations are of the facts that cause the changes in the weather. Major controls of weather are temperature, precipitation, humidity (including extent of cloudiness), wind velocity, and wind direction. The forecast is a pre-

diction of effects that are likely to be produced from causes which have been carefully studied.

In your study of weather in the United States you must recall that the United States is in the westerly-wind belt. You must recognize therefore that these conditions of weather slowly move across the country from west toward east. The "weather man" knows that the conditions which prevail a certain number of miles west of him on one day are likely to be the conditions that will prevail in his city on the following day. The accuracy of his predictions depends upon his ability to foretell from records gathered in many cities on one day the conditions that will prevail on the next day. The instruments just described are the ones with which the records are gathered.

The climate of a particular region is the average weather in that region. The daily weather of a place depends upon the conditions of the atmosphere as regards temperature, precipitation, humidity, wind velocity, and wind direction. Weather Bureau predictions are made by means of careful study and accurate instruments.

Can You Answer these Questions?

1. Does the barometer commonly register a greater pressure during a period of rain or during a period of fair weather? Why?

2. What is humidity?

3. Suppose air at 70° F. is nearly saturated. What happens if the temperature drops to 45° F.?

4. Is there any basis for accurate long-time weather predictions? Explain.

5. What is a simple explanation of a ring around the moon?

6. What is the difference between weather and climate?

7. Why is it safe to predict clear weather when a cold current of air is moving southward, gradually warming as it flows along?

8. Here are some of the instruments used by the Weather Bureau in its prediction of weather:

a. Mercury barometer
b. Mercury thermometer
c. Hygrometer
d. Aneroid barometer
e. Barograph
f. Metallic thermometer
g. Wet-bulb thermometer
h. Wind gauge
i. Thermograph

Do you know what each of these instruments is used for? Can you explain the scientific principles of these instruments?

9. What do we mean when we say that the air pressure is a certain number of inches?

10. Why is the amount of water required to saturate the air different at different temperatures?

11. What is the dew point?

12. What is the meaning of the terms *absolute* humidity and *relative* humidity?

13. What are the four major factors of weather? How do you think each of these affects the weather?

Questions for Discussion

1. Does the professional "rain-maker" use scientific methods? Do you think he knows anything at all about science?

2. Should you call the "weather man" a scientist? Defend your answer.

3. Do any weather signs or superstitions have a scientific background? Can you name some that do and explain the reason why they may be accurate?

4. How do you think the weather forecast in an almanac is prepared? How does this differ from the methods used by the Weather Bureau?

5. To what extent are the weather predictions made by the Weather Bureau accurate?

6. How should you describe the climate of the United States? How should you describe the weather of the United States?

7. Very often in sea stories you read of the fear and worry that come with a falling barometer. What is meant by a *falling barometer* or a *falling glass*? Why should this cause anxiety?

Here are Some Things You May Want to Do

1. There are many excellent books on the weather. Try Van Cleef's *The Story of the Weather*, Humphries's *Fogs and Clouds*, or Brooks's *Why the Weather?* A book which is perhaps a little easier to read is Rolt-Wheeler's *The Boy with the U.S. Weather Men*. After you read any of these, tell your classmates whether or not you think they might be interested in reading the same book.

2. Have you a weather station in your vicinity? If so, have you visited it? If you make arrangements in advance, the men in charge will probably be glad to have you come. If you cannot visit it, perhaps someone from the station might be glad to come to your school and explain their work. Write and ask about it.

3. Make your own collection of weather signs and superstitions. Be sure to indicate which are only superstitions and which have some scientific basis.

4. As a class, write to the United States Weather Bureau at Washington, D.C., and ask for its list of publications. You may want some of these.

5. Keep a weather chart for your class. Record the temperature each day at the same time, the wind direction, whether it rains or not, and any other facts which you think valuable. Compare your record with the predictions in the local newspaper. Does it agree? What do you think is responsible for the differences?

6. Is it possible for you to find and record the relative humidity of your classroom or home each day? How should you do it? Do you think it would vary from day to day? How could you keep it constant?

Chapter IX · What is the Character of the Weather of the Westerly-Wind Belt?

In previous chapters of this unit you have found several references to winds and their importance to life upon the earth. Since an understanding of the winds is necessary to a complete understanding of weather as it will be discussed in this chapter, let us summarize some of the things you have learned from your observations.

You have seen many illustrations of the manner in which heat from the sun's rays causes the winds. Since the earth is heated unevenly, the gases of the air are forced to move as wind over the surface of the earth.

Winds are caused by uneven distribution of solar radiation

You will recall that the intense heat from the vertical rays of the sun within the torrid zone causes the air to expand. This expanded air, of course, is less dense than the colder air in regions to the north and to the south. The force of gravitational attraction is greater for the denser air than for the less-dense air, and the denser air spreads out over the surface of the earth, forcing the less-dense air upward. Air moves from a region where it is denser toward a region where it is less dense.

The air is hottest in the torrid zone and coldest in the frigid zones. The air flows on the surface of the earth in huge convection currents from the frigid zones toward the equator. At the equator the less-dense air is forced upward, and the round is completed as the less-dense air spreads out northward and southward, cooling as it goes, until finally it descends again to the surface of the earth. From the horse latitudes to the equator the air flows on the surface as the trade winds. From the equatorial belt of calms to the horse latitudes it flows high in the upper atmosphere as the anti-trades.

Some of the air carried by the anti-trades moves toward the north and toward the south into the temperate zones. You have learned how the rotation of the earth turns the course of these air currents more and more toward the east until they become westerly winds. Air currents flow into the temperate zones from the torrid zone and from the frigid zones.

Paul Hurd

Fig. 90. This Old Fir Tree at the Top of the Continental Divide gives Evidence of the Force of the Prevailing Westerlies

In what direction is east in this picture?

The whole mass of air within the temperate zones moves from the west toward the east, but within this large mass there may be air currents in any direction. The prevailing winds are the westerlies. Local winds are variable. The differences in pressure between air of the torrid zone and air of the frigid zones causes air to flow across the temperate zones. This shift of air is one of the causes of the variable winds. These variable winds, in turn, are a chief cause of weather. In this study of weather we shall be especially interested in that of the north temperate zone. Most of North America, most of Europe, and most of Asia are in the north temperate zone.

Variable winds cause changes in weather

From your ordinary observations you may not be aware of the fact that you live in the belt of the westerlies; for, as you know, the wind does not always blow from the west. It may blow from any direction. An observation like the one in Fig. 90 furnishes convincing evidence that

winds blow from the west more than from the east. This old fir is growing on the crest of the Continental Divide in Colorado. There are no branches on the western side of the tree, for its lack of protection from the prevailing westerlies has prevented their growth.

A. What are Cyclones and Anticyclones?

On account of the difference in pressure in different regions and on account of the rotation of the earth the air currents in the westerly belts frequently move in great circular whirls. A region of air spread over a large area and moving about a center of low pressure is called a cyclone. You must not think that the winds of a cyclone are destructive. They may occur as nothing more than a gentle breeze. Hurricanes and tornadoes are the destructive winds.

These great masses of whirling air called cyclones are regular phenomena, or occurrences, of the temperate zones. The Weather Bureau determines their position and charts them on a map every day. In Fig. 91 is a photograph of one of these maps. Every city that is marked with a circle is a station of the Weather Bureau. An observer in each station takes observations every morning at eight o'clock, Eastern standard time. He records air pressure, temperature, wind direction, wind velocity, humidity, clouds, and rain or snow. These recordings are sent to a few central stations, which receive the reports of observations taken in cities distributed over most of the continent. From these observations the charts are made.

Lines called isobars are drawn on the map through points reporting the same air pressure. The difference in pressure between the lines is 0.1 inch. When these lines are completed, it may be seen that they form nearly concentric circles, that is, circles drawn about the same center. It may be seen, too, that the small circle nearest the center is drawn through points reporting the lowest pressure.

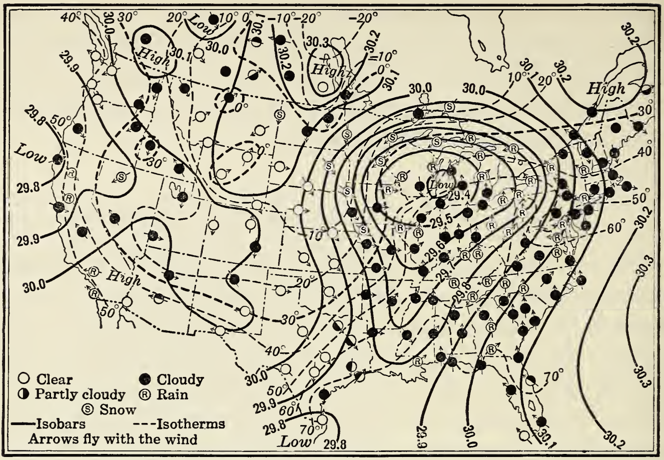


Fig. 91. The Weather Maps published by the Weather Bureau indicate Weather Conditions all over the United States

This map illustrates an easily distinguished low-pressure area. Notice the direction of the winds

Outward from the center the pressure is greater. The center is therefore a region of lowest pressure. Arrows on the map show the direction of the wind. As you might expect, the general direction of the wind is from the region of highest pressure toward the region of lowest.

Note, however, that the wind is deflected, or turned, from a straight line, and that it moves as a whirl toward the center of the low-pressure area. Notice, too, that the air whirls about the center in a direction opposite to the direction in which the hands of a clock move. The cyclone is therefore a huge mass of air whirling in a counterclockwise direction and moving inward toward a center of low pressure. This is illustrated in Fig. 92, *b*.

Cyclones are winds over large areas of low pressure

At the center the air is rising and spreading outward. At the same time the whole mass is shifting along with the prevailing westerlies from west to east about five hundred

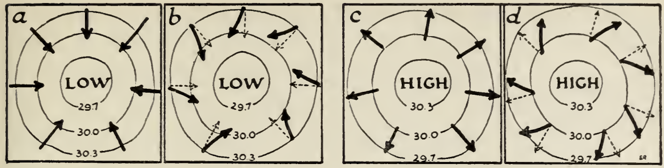


FIG. 92. The Rotation of the Earth affects the Direction of the Wind Currents in Lows and Highs

In *a* and *c* is shown the direction of wind currents as they would be if the earth did not rotate; in *b* and *d* is shown the change in direction due to rotation. The changes as shown would occur in the Northern Hemisphere. In the Southern Hemisphere the changes would be in the opposite direction

miles in twenty-four hours. As it moves over a given region, the direction of the wind in that region gradually changes.

You may see now one of the causes of variable winds. With the weather map before him the forecaster ("weather man") has knowledge about how the wind will probably change, and from other information he knows whether the change is likely to bring warmth or cold or rain or snow. He also knows whether he should expect the winds to increase or diminish in velocity. Suppose we study such a map with some care.

On the map in Fig. 91 the city of Chicago is near the center and is in the position of lowest air presure. When this map was made, the air pressure (barometer reading) near Chicago was 29.4 inches. As you may see, the difference in pressure between one isobar and another is 0.1 inch. In the city of Providence, which is located near the outer limits of the area of this cyclone, the air pressure is 30.1 inches. This difference in pressure of 0.7 inch causes the wind to blow toward the center of the cyclone. Since air is moving toward the center from all directions, the air in the center must be forced upward. The map shows clearly that the air currents whirl inward and that their direction is counterclockwise. Fig. 93 is a diagram showing conditions within a typical low-pressure area.

Anticyclones are winds over large areas of high pressure

A weather map may show a center of high pressure. A region of high pressure is called an anticyclone, for in a sense it is the opposite of a cyclone. The air pressure in the center of the anticyclone shown in Fig. 94 is 31.4 inches. Since the pressure is less at positions away from the center, the winds flow outward. The arrows in Fig. 92, *d*, show the direction of the wind currents about a region of high pressure. Notice that the winds whirl outward and that in this case they turn clockwise, that is, in the same direction that the hands of a clock move. A cross section through such an area is shown in Fig. 95.

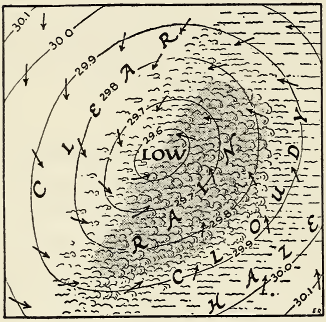


Fig. 93. A Cyclone, or Low

This is a huge mass of air moving inward toward a center of low pressure. In the Northern Hemisphere it whirls in a counterclockwise direction

Temperature and wind direction are also recorded on the maps. The dashed lines, called isotherms, are drawn through points that have equal temperatures. Notice that the isotherm cuts through the cyclone in a line from northeast to southwest. The direction of this line shows that it is warmer in the eastern portion of the cyclone and colder in the western portion. You may see, too, that the eastern part of the cyclone is in the path of winds chiefly from the south. The western part of the cyclone is in the path of winds chiefly from the north. The temperature is of course influenced by the direction from which the winds blow.

Other facts are shown on the maps. If it is cloudy when an observation is taken, the small circle that shows the position of the station is blackened. The letters *R* and *S* are used to indicate rain and snow. It is interesting to

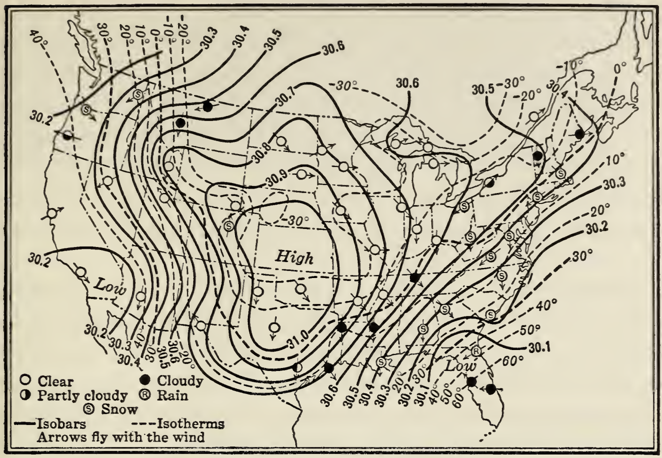


Fig. 94. This Weather Map illustrates an Easily Distinguished High-Pressure Area

note, too, that the difference in pressure between two points may be readily seen from the map. When the isobars are close together, there is a greater difference in pressure than when the isobars are far apart. When the difference in pressure is greatest, the winds will blow with greatest force. In which of the locations shown were the winds strongest when this map (Fig. 94) was made?

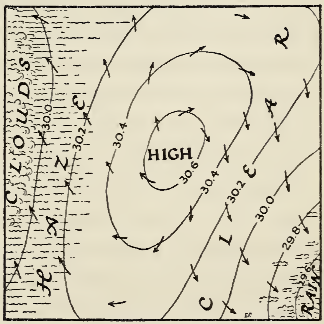


Fig. 95. An Anticyclone, or High

This is a huge mass of air moving outward from a center of high pressure. In the Northern Hemisphere it whirls in a clockwise direction

The general direction of the wind in the southern section of a cyclone is toward the north, and the air in the wind is cooled as it moves northward. As it is cooled, the water vapor condenses,

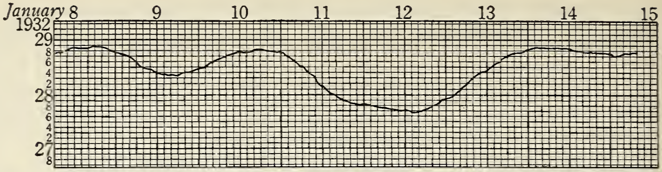


Fig. 96. Highs and Lows pass across the Country in Regular Succession

The graph shows barometer readings at Huron, South Dakota, for one week

forming clouds and rain. A wind from the south, therefore, is likely to bring rain. The general direction of the wind in the northern section of a cyclone is from the north. As the air moves southward, it is warmed; and as it is warmed, it gathers moisture. A wind from the north, therefore, is likely to bring clear weather.

The cyclones and anticyclones move across North America from west toward east, carried along in the westerly-wind belt. Fig. 96 is a graph showing the changes in barometer readings at a South Dakota Weather Bureau station. Notice the succession of lows and highs. How many low-pressure and high-pressure areas can you find in this graph? Since the "weather man" knows from careful observation the conditions that prevail within these whirling masses of air and since he knows the direction in which the air will move within these areas, he can predict with considerable accuracy the kind of weather that they will bring. What predictions can you make from a weather map?

Suppose the weather map shows a low-pressure center over Iowa, with clouds and rain. The forecaster knows that he may expect clouds and rain in New York within twenty-four or thirty-six hours. He knows, too, that, following the passing of the low from Iowa, there will come northwest and north winds. These will bring clear and cooler weather. The forecast for the day following these observations may be rain in New York and clear and colder in Iowa.

The conditions which produce a cold wave may be easily recognized. In Figs. 97–100 are shown the weather maps of February 25, 26, 27, and 28, 1934. These maps show the weather changes that came during this interval, and these are typical of the changes that may be observed as a "high" moves across southern Canada and the northern United States. In winter such a disturbance usually brings severe cold. Let us study these maps carefully. Notice that the map for February 25 shows a high-pressure area over the Dakotas, Montana, and Saskatchewan. The barometer reading in the center of this area is 30.5 inches. There is a center of low pressure over eastern Texas and Arkansas, with a barometer reading of 29.7 inches. Within the area of high pressure and to the east of it the temperatures in different stations of the Weather Bureau range from 20° F. to 40° F. Follow the isotherm of 0° F. It passes through southern Minnesota and Nebraska. Notice also the isotherm of 30° F. It passes through Kentucky, Tennessee, Arkansas, and northern Texas. New Orleans, with a temperature of 70°, is as warm as a pleasant summer day. From study of the weather maps you may learn the direction of the wind and you may learn of the conditions which make it blow. You may predict from these facts that the cold wave will move southward and eastward. Do you see why? Is this prediction correct? Look at the map for February 26. During the interval of twenty-four hours the center of high pressure has moved southwestward. Its center is now over Kansas and Nebraska. The region west of the Mississippi River in which the temperature on the day before was between 0° F. and 10° F. now has a temperature ranging between 0° F. and – 20° F. In the city of New Orleans the temperature has dropped thirty degrees during twenty-four hours. In southern Ontario the temperature on the 25th was as low as – 40° F. On the 26th it has fallen to – 50° F. A center of low pressure was over eastern Texas on the 25th. It is over the coast line of the middle Atlantic

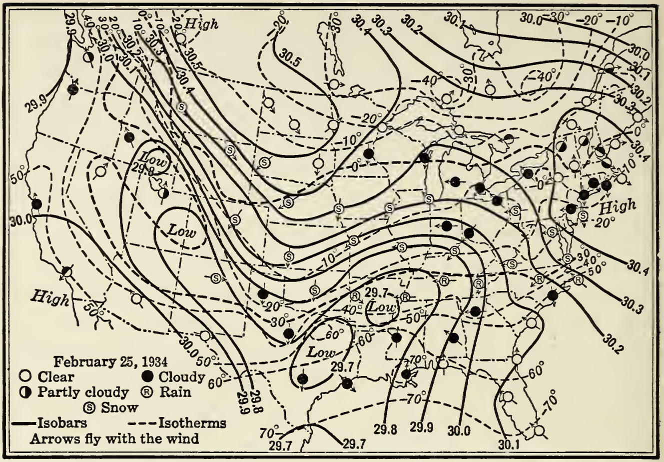


Fig. 97. Can you find the High-Pressure Area over the Dakotas, Montana, and Saskatchewan?

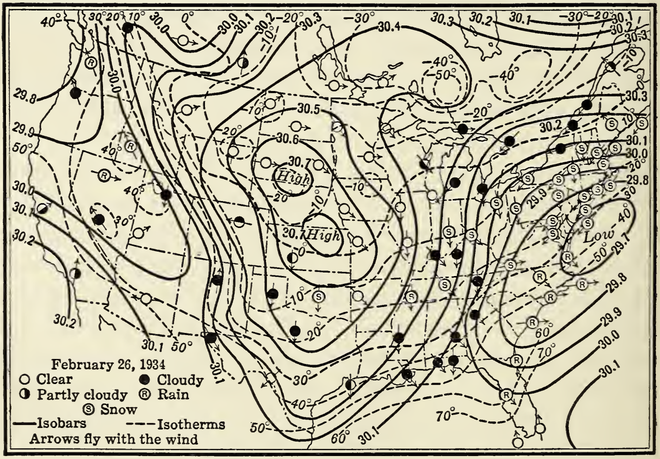


Fig. 98. What has happened to the High-Pressure Area within a Period of Twenty-four Hours? What other Changes have Occurred?

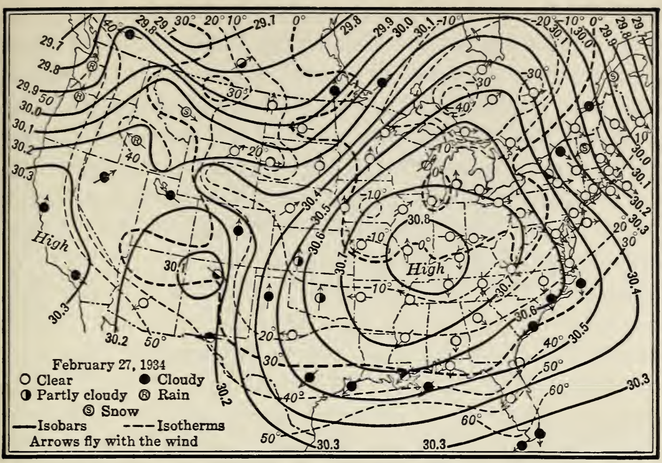


FIG. 99. Why is the Weather in the South Atlantic and Gulf States Much Colder on February 27 than it was on February 25?

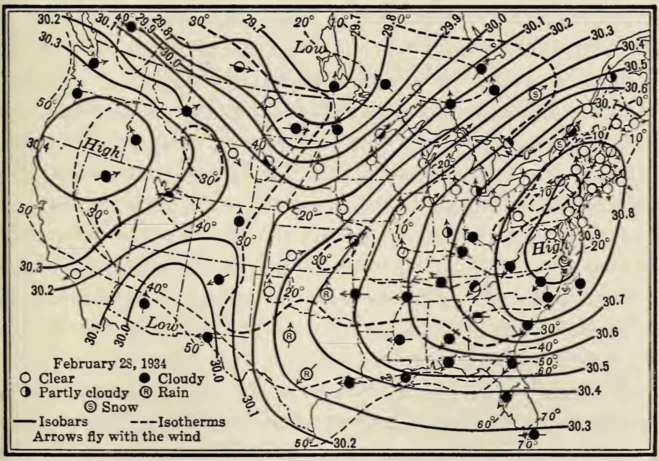


FIG. 100. Are the Weather Conditions shown on this Map Different from those in Fig. 97? In what Ways?

states on the 26th. What change in the direction of the wind in the states east of the Mississippi River has come during the preceding twenty-four hours? On this date the weather forecaster predicted "much colder" for all the south Atlantic states and the Gulf states. Do you see why? Turn to the map of February 27 and see if his prediction came true.

The center of high pressure has moved eastward, and the center of low pressure has moved northeastward. During forty-eight hours the temperature in New Orleans has fallen from 70° F. to 30° F., and a temperature of freezing has spread over all the Southern states except Florida. Notice the direction from which the wind is blowing in Montana. The region of high pressure is now far to the south. Stations which reported severe cold only forty-eight hours before are now much warmer, and the forecast on the 27th was for a further rise in temperature in Montana of from twenty to fifty degrees.

On the 28th the center of high pressure is over the eastern seaboard, and a center of low pressure is near the region in Saskatchewan, which was the center of high pressure on the 25th. The passage of the high-pressure and the low-pressure areas has brought changes in the direction of the wind. In general, the winds from the north bring cold and the winds from the south bring warmth. The changes that come with the passage of highs and lows are of such a character that they may be predicted in advance. The weather forecaster studies the highs and lows and the weather conditions within them. He bases his prediction upon his knowledge of the manner in which these disturbances in the atmosphere move across the continent.

The conditions that produce a hot wave are in a sense the opposite of those that produce a cold wave. In this case the high pressure is over the southern United States and the warm air from the south flows northward. The conditions shown in these maps are typical of changes that come and go as a cold wave passes.

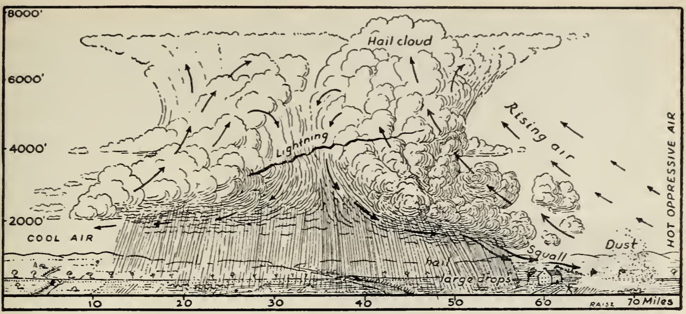


Fig. 101. A Thunderstorm is a Familiar Local Storm

The drawing represents a cross section through a thunderstorm

With a weather map before you, you can predict the coming of a cold wave and the coming of a hot wave. You might successfully predict rain or snow; but for a full prediction you would refer the matter to an expert, and this expert would be a "weather man."

B. What is a Thunderstorm?

Within the cyclones and anticyclones local storms of more or less severity may develop. The thunderstorm is a familiar form of local storm. Thunderstorms form in the open prairie, and they form in the mountains. They occur with much greater frequency in summer than in winter. A passenger in an airplane flying at high altitude over the Western Plains may see two or more thunderstorms in progress at the same time. On high mountain peaks these storms come almost every day during midsummer.

A thunderstorm is in a sense a miniature cyclone. Within a thunderstorm there is a strong upward current of air. The heated air from the surface is carried to high altitudes, and as it rises it is cooled. Cooling causes some of the water vapor carried by the air to condense, and the first condensation forms

A thunderstorm is a miniature cyclone

the great white bank of clouds. As the clouds get denser, streaks of lightning appear and rain starts to fall. Such cloud banks may rise in the air as high as three or four miles.

Within the storm the winds may be blowing furiously. The storm as a whole is moving along on the surface toward the east. The winds are circling about the center of the storm in a counterclockwise direction, whirling inward and upward. In Fig. 101 is a diagram of a thunderstorm.

U. S. Weather Bureau

Fig. 102. Sometimes Hailstones form as Large as Tennis Balls

The man is holding an egg in one hand and a hailstone in the other

An interesting account of these storms is given by a bold aviator who purposely drove his plane into one of them. While within it he completely lost control of his plane. The winds carried him upward with great speed for some thousands of feet. After a time, however, he escaped from the dangerous adventure without damage to his plane or himself and flew back to the landing field. The experiences of this aviator furnish abundant evidence of powerful forces within thunderstorms.

Heavy rainfall may come from a thunderstorm, but the fall usually lasts only a short time. Sometimes the precipitation is in the form of hail. Under certain conditions hailstones form that are as large as tennis balls. Look at Fig. 102. You may understand from the aviator's experience how these are formed. There are clouds high in the air, and precipitation may be formed as snow. As it falls,

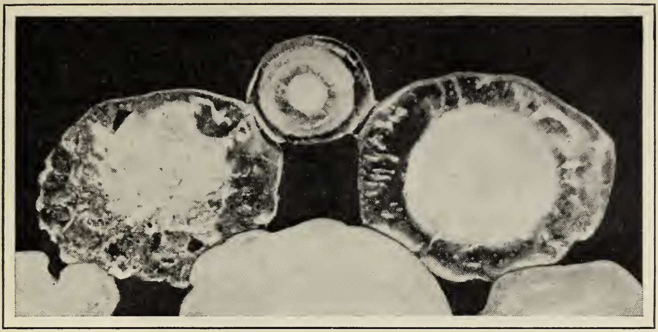


FIG. 103. Notice the Distinct Layers in the Hailstone cut in Half

it meets the warm rising air and melts. The rising air currents, which are strong enough to raise an airplane, are also strong enough to carry back, up to the region of cold, the water that formed from the snowflakes. Now the water changes to ice and again starts downward. It may again be caught in the upward air currents and carried again into the region of cold. As it moves through the clouds, more water forms on its surface; and as this freezes, the hailstone gets larger. It may be caught and carried back several times. Each trip upward adds more ice to its surface, until finally it is so heavy that it falls to the earth. Hailstones may show on careful examination several distinct layers of frozen rain. In Fig. 103 some hailstones are shown cut in halves. These large pieces of ice are further evidence that there is a powerful draft of rising air within a thunderstorm.

C. What is a Tornado?

The tornado is the most violently destructive storm of the United States. It is somewhat like a thunderstorm, but it is more destructive. These storms are likely to develop when a cold air current from the north meets a warm air

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Fig. 104. The Tornado is the Most Violently Destructive Storm of the United States

These pictures, taken at short intervals, show a tornado from its formation until the time it struck. Notice the typical funnel-shaped cloud, the narrow path in which the storm travels, and, in the last picture, the vast quantity of dust which the rapidly moving cloud has picked up

U. S. Weather Bureau

Fig. 105. Some Peculiar Things happen during a Tornado

Notice the plank driven through a tree, and the straws driven into pieces of wood

current from the south. When this happens, the air may be thrown into a violent whirl. The whirling air of a tornado always turns in a counterclockwise direction in the Northern Hemisphere. Its forward motion (always toward the east) may be as fast as fifty miles per hour. The path of the storm is usually not more than a few hundred feet wide, as you can see from Fig. 104. The air is whirling so fast that it is thrown away from the center of the whirl, producing a region of extremely low pressure. When the center of the storm passes over a house, the air pressure on the outside of the house is lowered so much and so quickly that the

Tornadoes are destructive to property and to life

pressure from within sometimes causes the walls of the house to fall suddenly outward. The walls of a room may be destroyed, leaving objects such as table lamps, telephone stands, and other furnishings not at all disturbed.

U. S. Weather Bureau

FIG. 106. When a Storm Similar to a Tornado forms over the Water, it is called a Waterspout

Compare the form of this waterspout with that of the tornado in Fig. 104

Some very peculiar things happen during a tornado. Feathers have been plucked from chickens by such storms. As the region of low pressure passes over the chicken, the air in its quills expands; and this causes the feathers to pop out. If the air pressure on a bottle is reduced sufficiently, the cork may be forced out of the bottle by the pressure of the air within. Corks are frequently blown from bottles as a tornado passes over. Animals may be lifted from the ground and carried for long distances. Strange as it may seem, straws carried by the wind may be driven into boards and trees. Look at Fig. 105. After one tornado a pine stick was found driven entirely through a poplar tree that was eighteen inches in diameter. In another case a pine board one inch thick and five inches wide was driven through a second board that was two inches thick. There is one case on record in which a ma-

chine weighing two thousand pounds was moved about two hundred feet by the force of a tornado.

Storms similar to tornadoes sometimes form over the sea. Such a storm over the sea is called a waterspout. One is illustrated in Fig. 106. The rapidly whirling air may suck the water up from the ocean. Then if the storm moves over land, the land may be drenched with salt water. Probably you have heard of fish falling with rain. Such incidents are quite unusual, but they have occurred. Fish swimming near the surface may be lifted from a lake or from the ocean by the rapidly whirling air and carried to the land with the water that is raised by a waterspout.

D. What is a Hurricane?

Hurricanes begin over the islands of the West Indies

Another destructive storm is the tropical hurricane. These storms begin over the islands of the West Indies, in the region of the horse latitudes. Hurricanes are in a sense intermediate in severity between cyclones and tornadoes. Cyclones are not to be thought of as destructive storms at all. They are, however, masses of air circling in a counterclockwise direction about a region of low pressure. Cyclones cover a very large area. Tornadoes are also masses of air circling in a counterclockwise direction about a region of low pressure. They cover a small area, but the winds are terribly destructive. A tornado lasts for only a few minutes. Within a hurricane the winds circle in the same direction as in a cyclone and a tornado. These storms may be very destructive. The winds are less severe than in a tornado, but they may continue without interruption for some two or three days.

Hurricanes are often carried, by the force of the trade winds, westward from their place of origin to the region of the Gulf of Mexico before they swing northward into the westerly-wind belt. The most destructive hurricane ever

FIG. 107. The Winds accompanying a Hurricane may be very Destructive

experienced in the United States was carried westward from the West Indies as far as Galveston, Texas. The destruction of property and the loss of life in Galveston were terrific. From here it passed northward and eastward over the states to the Great Lakes and from there on out to sea over the mouth of the St. Lawrence River. This was a storm area about six hundred miles in diameter. Within the storm the air was moving in a great whirl with force enough to break limbs from trees and do damage to dwellings. Look at Fig. 107, which illustrates typical hurricane damage.

Frequently these storms strike with great force on the coast of the south Atlantic and then move northward, destroying property all along the way. Many of them pass northward over the ocean, and in these cases their damage is only to the ships caught in their paths. In Fig. 108 is a scene from the deck of a liner in a heavy storm. The Weather Bureau charts the paths of these storms and by means of the radio warns ships to keep out of their way.

FIG. 108. The Force of the Wind in a Heavy Storm may be seen in these Mountainous Ocean Waves

There is one especially treacherous feature about the hurricane. You may think of the hurricane as a whirling wind moving with violence about a center of low pressure. Within the center of low pressure there is a region of calm. The air is rising here, but to an observer the motion of the air is not obvious. As the hurricane passes over a region, its approach is announced by strong winds. As the center approaches, the wind ceases and it seems as if the storm is over. As the center passes, however, the other side of the whirl comes on and the region is again struck by violent winds. The location over which the center passes experiences, therefore, two storms.

Some years ago the center of a hurricane passed directly over a large city. With the approach of the storm there was the terrific wind, and considerable damage was done. When the center of the storm came, the wind ceased; and people, thinking the storm was over, came out of their homes to view the damage that had been done. After an

interval of about two hours the destructive winds came again. This time the people were caught out of doors less well protected, and the loss of life from the second half of the storm was greater than from the first. While the center of this storm was over the city the barometer registered 27.50 inches. This is the lowest sea-level reading ever recorded in the United States. Notice in the barograph reading illustrated in Fig. 109 that the pressure went down suddenly and then rose again as the center of the hurricane passed.

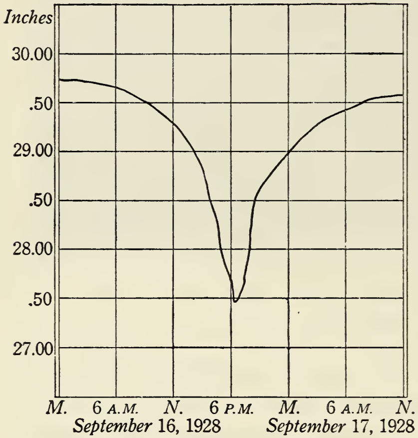


Fig. 109. In this Barograph Reading is recorded the Progress of a Hurricane

How long did it last? When was the center of the storm reached? What was the lowest air pressure recorded? What evidence is there that the pressure went down suddenly and rose again?

There are storms similar to hurricanes in other parts of the world. The typhoons of the Indian and the Pacific oceans are similar in origin to the hurricanes of the Atlantic, and they are equally destructive.

The circulation of the air and the violent windstorms that move over North America have their origins in solar radiation, for it is heat from the rays of the sun that causes the winds to blow. These storms are strong reminders that energy from the sun works powerful changes on the surface of the earth.

It is only in the temperate zones that these storms can develop. Europe and Asia, in the north temperate zone, and southern Australia and the southern tips of South America and Africa have similar ones. In none of these

places, however, are the storms just the same as ours, for their character is influenced by mountain ranges, nearness to the ocean, inland lakes, and other things. In any case these storms develop in air currents that flow back and forth across the temperate zones between warm regions about the equator and cold regions about the poles. These currents are driven by forces which have their origin in solar radiation, and they are influenced by the rotating and revolving earth over which they flow. The weather is a product of these influences.

The weather of the westerly-wind belt is due to a succession of low-pressure and high-pressure areas called cyclones and anticyclones. These, in turn, are due to the influence of solar radiation upon the surface of the earth.

Can You Answer these Questions?

1. Why are variable winds the chief cause of weather?

2. Why is the United States said to be in the belt of the prevailing westerlies?

3. What is a cyclone?

4. What is an anticyclone?

5. What is the difference between a cyclone and a tornado?

6. What is the meaning of the isobars on a weather map? What is the meaning of the isotherms?

7. What kind of weather do you associate with cyclones? with anticyclones?

8. What are the conditions that produce a cold wave?

9. What are the conditions that produce a hot wave?

10. What are the weather conditions under which thunderstorms may be expected?

11. How is hail formed?

12. What is the funnel-shaped cloud in a tornado? What causes it?

13. What is a hurricane?

14. Why is it that in the center of a hurricane the wind may die down and then blow again with even greater force than before?

15. What is the definition of a *low*? of a *high*?

16. When do winds blow with greatest force, at the time of a small difference in air pressure or at the time of a great difference in air pressure? Which of the maps in this chapter best illustrates these conditions?

Questions for Discussion

1. Why do the winds in a cyclone move in a counterclockwise direction, while in an anticyclone they move in a clockwise direction?

2. Is hail formed in the same way as snow? frost? sleet?

3. Can you see any reasons why tornadoes are fairly common in the central part of the United States, but almost entirely unknown in New England? You may get some help in answering this question from either Van Cleef or Brooks, whose books are listed on pages 529 and 534.

4. Why are hurricanes usually formed in the region of the tropics? The books mentioned in question 3 will also help here.

Here are Some Things You May Want to Do

1. Prepare a booklet on "How the Weather Man predicts the Weather." Illustrate it with drawings or photographs of the instruments used, the types of records kept, and such other information as you think might make your story more interesting and accurate.

2. Make a collection of newspaper clippings about the weather. Cut out everything you can find for two weeks or more. You may want to arrange a bulletin-board exhibit of these clippings if they are sufficiently interesting.

3. Have you ever been in a tornado or a hurricane? Have you ever seen a region through which one has passed, a few hours

afterwards? If so, write an account of what these severe storms are like. Perhaps you may know someone else who has experienced one.

4. Read the United States weather maps every day for a period of two weeks. Try to learn how the "weather man" uses the information given on a weather map in predicting the weather. If you do not receive these maps at your school, write to the nearest Weather Bureau station and ask for them. They are free, provided you promise to display them where they can be easily seen.

5. Make a special collection of pictures and stories concerning tornadoes or hurricanes. See if you can find any examples of the freak damages done by these storms.

B. C. Hamilton

Fig. 110. Familiar Environments change as the Seasons Come and Go

These pictures show the same environment in summer and in winter

UNIT III

How do Plants and Animals live in the Climates of the Different Zones?

IN THE LAST UNIT you made many imaginary visits to different parts of the world. You traveled by airplane along the coasts and across the interiors of two large continents. You accompanied a group of explorers as they made their way along the equator. As a result of these imaginary explorations of yours you experienced many extremes of climatic conditions.

In tropical lands you saw equatorial rain forests, rich with plant and animal life the year round. You traveled up the Nile River, going from desert regions into dark, deep forests where life for men of the white race is almost impossible. You saw seasonal change marked only by changes in rainfall, with wet and dry seasons rather than hot and cold ones.

You visited desert regions in that belt of the world that lies between the tropics and the temperate zones. You found that these deserts, except on mountain tops, are hot, with but little rainfall. Therefore the deserts, in contrast with the rain forests, are barren of life. You also observed life in the temperate zone, including that of your own land. You had a glimpse of India with its three seasons.

Finally, beyond these temperate lands and waters, yoa found the frigid zones. Here the extremes from season to season were greatest.

From these and other observations you can decide that plants and animals are adapted to live in the conditions that are found around them. Since this is so, plants and animals of the frigid zones must be adapted to meet extreme changes. Plants and animals of the torrid zone, on the other hand, are adapted to a life which is more nearly uniform throughout the year. Living things seem well adapted to physical conditions of their own environment, and it is extremely difficult for them to change from one environment to another.

Let us now ask: How are plants and animals adapted to their environment? What changes take place in growth and life from season to season? from year to year?

Chapter X · How do Green Plants live through the Changing Seasons of the Westerly-Wind Belt?

The seasons of the westerly-wind belt are marked by changes in temperature. The extremes of winter come with cold waves and the extremes of summer with hot waves. The climate of summer, with warmth and rainfall, is generally favorable for plant growth. The winter season, with water often in the form of ice, is generally unfavorable for plants. Most of the United States and Canada lies within this belt of winds.

Throughout the region of the westerly winds the lower extreme in temperature may fall below the freezing point of water. How does this affect plant life? As you know, plants must have water if they are to live and grow. If water is frozen, then, plants cannot grow. There are regions within this wind belt where the winters are mild. There are also regions where the winters are quite severe. With few exceptions, however, plants and animals in the regions of the westerly-wind belts must be adapted to live through a period cold enough to change water in unprotected cells into ice.

The out-of-doors in winter is in many ways unlike the out-of-doors in summer. After frost has come and after the ground is frozen, the trees, except for evergreens, are bare. There are no green fields, and there are but few small flowering plants that can live through even moderately cold weather. Seeds that have formed during summer are distributed everywhere, but they must await the warm spring sun before they can start to grow. This change is very clearly illustrated in Fig. 110. Contrast the summer landscape with the same landscape in winter.

With the first warm days of spring, changes come quickly. These are illustrations of the response of living things to changes in their environment. The buds on the

trees begin to swell, and in a short time leaves appear. Seedlings soon set roots in the soil and spread leaves to the sunshine. In response to the continued warmth of the sunshine, blossoms form on small plants, on shrubs, and on trees. Life is soon in evidence everywhere.

Seasonal change brings a regular cycle, or round, of changes in living things. Plants and animals depend upon their physical environment; and as their environments change, they too must change in their manner of living. Animals depend absolutely upon plants for food. The character of the seasonal change in green plants therefore determines in large part the character of the seasonal changes in the activities of animals.

There are many differences in the manner in which plants are adapted to live through the changing seasons. Many grow from seed, produce more seed, and die, all during one growing season. Each year the life cycle is repeated. Such plants include corn, oats, peas, and beans, as well as many garden flowers. In others, including beets, carrots, mullein, turnips, and hollyhocks, the cycle runs through two years. Still others, such as trees, shrubs, and many herbs, live on and on from one season to the next. All these forms, however, are adapted to live through changing seasons.

A. What Conditions influence the Growth of Plants?

It may be winter when you begin your work with this unit. You may, however, study in your classroom the conditions that influence the growth of plants. Observations in the out-of-doors show the effect of cold. In the classroom you may study the effects of warmth, moisture, sunshine, and other conditions on growing plants.

Secure four small flowerpots and a glass tumbler. In three of the pots put some rich, moist soil. In a fourth pot put some very dry soil. In order that you may be sure that

Fig. 111. Plant Growth takes place Only under Favorable Conditions

This drawing illustrates the experiment described in the text

it is very dry, place the soil in an iron pan on a warm radiator and leave it overnight. For the fifth observation place a small sponge in the glass tumbler with just enough water to make the sponge moist. Now plant four bean seeds in each pot. Also place four seeds on the moist sponge.

Many factors in the environment affect growth

You may arrange these pots and the tumbler so as to show the effects of moisture, temperature, sunlight, and soil on the sprouting of seeds and the growth of the plants. If the weather is cold (near or below freezing), place one of the pots (1) containing moist soil out of doors. If the weather is warm, place it in a refrigerator. Place a second pot (2), containing dry soil in a warm room in sunlight. Do not add water to the dry soil. Place a third pot (3) containing moist soil in a warm dark cupboard or closet. Place the remaining pot (4) and the tumbler in good light in a warm room. The soil in this pot is moist. Keep it moist by adding water. Keep the sponge moist by adding water as needed.

The arrangement may be summarized as follows:

	Moisture	Temperature	Lighting	Planted In
Pot 1 . . .	moist	cold	light or dark	soil
Pot 2 . . .	dry	warm	light	soil
Pot 3 . . .	moist	warm	dark	soil
Pot 4 . . .	moist	warm	light	soil
Tumbler . .	moist	warm	light	sponge

Here are some of the things you may see. The seeds in the pot that has been kept cold (1) will probably not grow.

Warmth and moisture are necessary for plant growth

Bean seeds do not sprout in cold soil. These seeds will grow only when the temperature of the soil in which they are planted is above 45° F. Similarly, no growth may be expected in the dry soil (pot 2), for seeds will not sprout unless they are moist. Continue observations through several days.

Fig. 112. The Tallest Plants grew in Darkness

Compare these with your bean plants. (From Gager's *Fundamentals of Botany*. Courtesy of P. Blakiston's Sons & Company, Inc.)

The importance of sunlight may be seen from observation of the pot (3) that was kept in darkness. The seeds will sprout if they are kept warm and moist. At the end of a week the stems of these plants are probably longer than the stems that grew in the daylight. Notice that these plants are not green, for the green coloring matter called chlorophyll does not develop in darkness. In the darkness these plants do not make food. The only source of food for them is the food stored in the seed.

Sunlight is necessary for growth of green plants

Even though there is plenty of good soil, moisture, and air, the plants growing in darkness will die as soon as the foods stored in the seeds are exhausted. Fig. 112 shows plants that grew in sunshine and plants that grew in darkness.

In only one of the pots does healthy, vigorous growth continue. This is the one (4) in which there are both moisture and warm soil, and in which the plant is exposed to sunlight.

FIG. 113. Growing Plants sometimes seem to reach for Sunlight

From what direction do you think the light came in each of these pictures? (From Gager's *Fundamentals of Botany*. Courtesy of P. Blakiston's Sons & Company, Inc.)

You may be interested in taking further observations of the effects of sunlight. Notice that healthy plants seem to grow toward the light of the window, as shown in Fig. 113. The leaves spread, too, so that the sun shines directly upon them. Look at the leaf pattern in Fig. 114. You may be able to see that the leaves really do turn with the sun as the sun moves across the southern sky. What will happen when you turn the plant halfway around to a position in which the leaves are not turned toward the sun? The position of the leaves will change, and after a time they will again be "facing the sun."

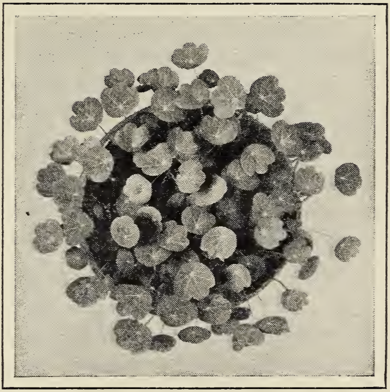


FIG. 114. Green Plants cannot grow without Sunlight

Notice how the nasturtium leaves have spread in growing, so that each leaf is exposed to light. (From Gager's *Fundamentals of Botany*. Courtesy of P. Blakiston's Sons & Company, Inc.)

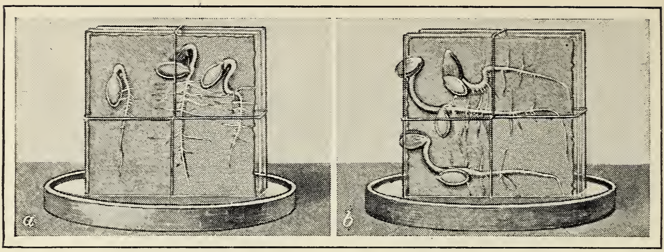


FIG. 115. Plants are affected by the Force of Gravity

The seeds on the sponge will sprout and grow vigorously for a time. They have warmth, sunlight, and moisture. Green chlorophyll forms in the cells, and roots extend downward into the sponge. Conditions seem favorable for growth, except that there is no soil. After a few days these plants wither and die. Growth cannot continue, for the sponge does not furnish to the plants the minerals that are necessary for growth.

Soil is necessary for plant growth

Another arrangement for the study of sprouting seeds may be set up as shown in Fig. 115, *a*. Some flat seeds such as squash or pumpkin are mounted on a piece of blotting paper between two squares of glass. The squares are held together with a rubber band or a piece of string. These squares may be placed upright in a dish with just a little water. In this way the blotting paper and the seeds may be kept moist.

In a few days roots and stems develop. Notice that the roots grow downward while the stem grows upward. After the roots and stems have grown a little, tip the plates to one side and again observe results. Notice that in whatever way you turn the plates it is only a little while until the tips of the roots have turned downward and the tips of the stems have turned upward. This is shown in Fig. 115, *b*. This illustrates the manner in which roots and stems are affected by gravity. Roots generally grow toward the center of

Plants are affected by the force of gravity

the earth, and stems generally grow away from it. Stems and roots are unlike in the way in which they act.

In warm moist air the young plants grow rapidly. The roots behave almost as if they were seeking for soil, and the stems almost as if they were seeking sunlight. A short distance back from the tip of the root you may see the root hairs. Under a microscope these may be seen to be outgrowths from cells. If the plant were growing in soil, both water and minerals would enter the plant through these tiny root hairs.

Green leaves soon form on the tiny plants under the glass. All conditions necessary for growth seem favorable, except one. There are warmth, moisture, and sunlight. The plant grows vigorously for a few days; but as time passes, it wilts and dies. Why? It is like the seeds growing on the sponge. Growth continues only so long as the food in the seed lasts. There is no soil from which the roots may secure the substances necessary for life.

Freezing bursts plant cells

It is easy to see that a little plant is very delicate in construction, and it is not surprising that it cannot grow in cold weather. Water freezing in the cells would surely cause them to burst. This is exactly what does happen when plants are killed by frost.

These observations show clearly some of the effects of gravity, moisture, temperature, sunlight, and soil. In your experiments you have controlled conditions artificially. Out of doors, in its natural environment, the growth of the plant may be affected by the same influences. It cannot continue to grow without soil. The roots grow downward, and the stem grows upward. The bean seed cannot grow in a hot, dry desert nor in frozen soil. It cannot grow in the dark, and it fails to develop into a strong, healthy plant when growing in the shade. Healthy growth requires rich, warm soil and plenty of sunlight and moisture.

If you followed the growth of a bean plant through the spring and summer, you would learn something about

how it lives from one season to the next. A careful examination of a bean seed as it sprouts on a moist sponge shows that in the process of growth the seed splits into two parts. The young plant appears from between these two halves. The stem soon spreads green leaves to the light. The roots grow downward, weaving in and around the openings through the sponge. In the soil the process of growth takes place in the same manner. When growth starts, there are no roots fastened in soil and no green leaves. During the interval in which the young plant is setting itself in the soil, growth is from the food stored in the two halves of the seed. You may learn by observation that these two halves gradually wither away as the food that was stored in them is changed into root, stem, and leaf.

During the first stages of growth the plant gets food from the seed

If conditions are favorable, the plant will have established itself in the soil in a few days. There will be many branching roots. Near the ends of each root are the same delicate root hairs that you saw on the plants growing between glass. Through them water from the soil, with minerals dissolved in it, enters the plant and passes upward through the stem to the green leaves. In the leaves the materials from the soil and the air are changed into food. Before the food stored in the seed is exhausted, the plant is prepared to make its own food. As the process of growth continues, more leaves are formed and the roots extend farther into the soil. In Fig. 116 these steps in the growth of a bean plant are illustrated.

Materials from the air and soil are changed into plant food

The process of food-making in green plants is called photosynthesis. The first product of photosynthesis is sugar. This may be changed to starch. Other forms of food, known as proteins and fats, are made in green plants. You may learn about the process of food-making from a study of the things that go on inside the plants.

Photosynthesis is a process of food-making in plants

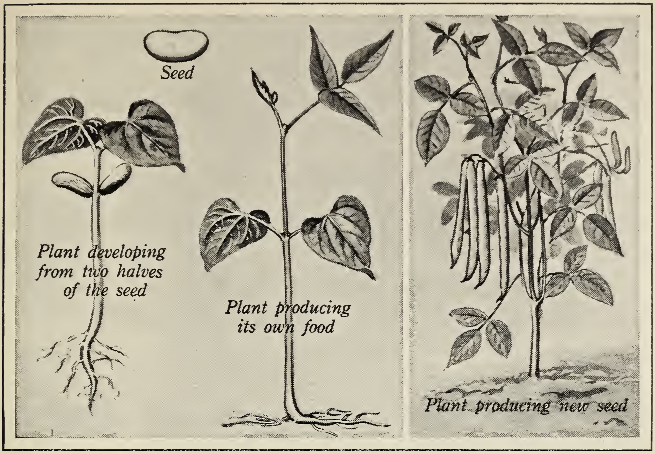


Fig. 116. In the Life Cycle of the Bean Plant, the Mature Plant produces Seeds which develop into New Plants the Following Season

Many other plants follow this same cycle

There is a continuous flow of water upward from the roots, through the stem, and to the leaves. On the undersurfaces of the leaves there are little openings called stomata. These are so tiny that they may be seen only with a microscope. Some of the water that comes from the soil passes out from these stomata by evaporation. This flow of water from the roots through the stem and leaves and out through the stomata is sometimes called the transpiration stream.

Air also passes into and out of the leaves through the stomata. You may know that some of the carbon dioxide enters the leaf through the stomata and passes through the walls of the cells inside the leaf. It is in the cells in the presence of the green chlorophyll that a chemical change takes place, changing carbon dioxide and water into sugar.

You will study the process of food-making again at a later time. At this point you should understand that all

the material composing the plant is manufactured from materials that enter the plant from the soil and from the air. This process of growth goes on only in the light and requires warmth, plenty of moisture, and rich soil.

B. What are Seeds and How are they Produced?

If you will follow the growth of the bean plant, you may see that after a time buds form, and in a little while these unfold into blossoms. Growth has continued until the plant now has well-developed leaves and a good bed of roots in the soil. It is after the plant is well equipped to make food that the blossoms appear.

The buds from which the flowers will unfold are covered with tiny green leaves. These form the *calyx* of the flower. Inside the calyx are the delicately colored petals. These taken together form the corolla. Inside the corolla are the stamens, and among the stamens is a single pistil. Look at Fig. 118, in which these parts are shown.

The chief function of a flower is to produce seed. On the end of each of the stamens is a pollen cup, which you may see in the picture. When the flower is mature, the pollen has the appearance of fine, dry powder. In order that a bean flower may produce seed, the pollen of one flower must get over to the pistil of another flower. In some plants pollen is transferred by the wind, but in the case of the bean it must be carried by an insect, probably a bee.

Transfer of pollen is necessary for the production of seeds

The bee visits the flower to gather the sweet liquid called nectar, from which it makes honey. It also gathers pollen, which it stores away for use as food. The nectar is far down within the flower. It is not easy for the bee to reach it. To do so, the bee must force its way between the petals and stamens and over the upper end of the pistil. In the course of its work, the body of the bee becomes well dusted over with pollen grains.

FIG. 117. CARL LINNÆUS, *who introduced System into the Study of the Plant World (1707–1778)*

BORN in Sweden only a year later than our own Benjamin Franklin, Carl Linnæus belongs to the same century as James Watt, William Herschel, Leeuwenhoek, Priestley, Kant, James Bradley, and Henry Cavendish. As was the case with so many other boys of his day, his parents wanted him to enter the Church. As a second choice they were willing that he should study medicine. When young Carl went away to the university at Uppsala, however, his one absorbing interest was botany, the study of plants. A few years later he became professor in the same university and was put in charge of the botanical garden. He traveled through many parts of Europe, including bleak Lapland, and obtained specimens of rare plants for his garden. So many thousands of new names were confusing, to say the least; and how should he name the plants for which he could find no previous names? Linnæus, having an orderly mind, set out to classify all the plants he had. He divided them first into a few large groups on the basis of certain outstanding characteristics. These larger groups he subdivided, and the smaller groups were divided and divided again. He gave each kind of plant two Latin names, so that anyone of any nationality could tell exactly to what group it belonged and which member of that group it was. If today you see a Latin name followed by the letters *Linn.*, you may be sure it is one of the many plants classified and named by Linnæus.

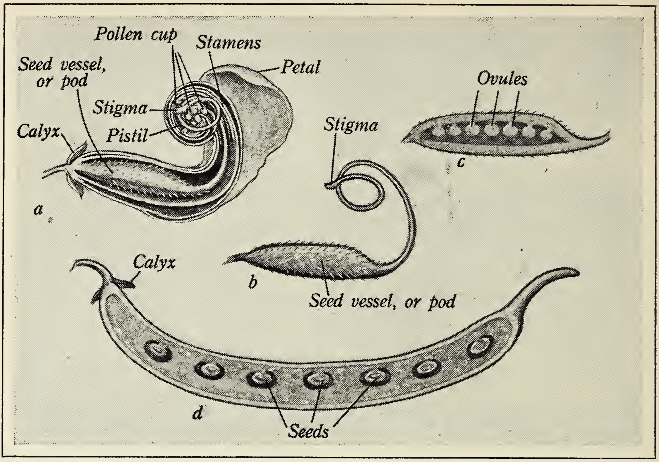


Fig. 118. The Development of a Bean Plant from Flower to Seed

a is a cross section through a bean flower ; *b*, pistil enlarged ; *c*, section lengthwise through the seed vessel, showing ovules (the stigma of the flower has withered and dropped off) ; *d*, section through maturing pod, showing developed seeds

In the mature bean flower the upper end of the pistil is covered with a sticky substance. As the bee crawls in between the petals, some of the pollen grains gathered from the stamens of another flower are caught by the sticky substance on the pistil. This transfer of pollen from the stamen of one flower to the pistil of another is called cross-pollination. As soon as the pollen grains have been deposited on the sticky part of the pistil, other things begin to happen.

The pistil itself is complex, as you can see from Fig. 118. The sticky end, on which pollen is deposited, is called the stigma. The base of the pistil is somewhat enlarged. This enlarged part becomes the seed vessel, or pod. Within this enlarged portion in the pistil are undeveloped seeds called ovules, and within each ovule is a tiny part called an egg nucleus. In order that an ovule may develop into a seed, the egg nucleus within it must combine with a sperm nucleus that is contained within a pollen grain. The pollen

grain deposited on the stigma by the bee develops a tube which extends downward in the pistil and penetrates the egg nucleus in the ovule.

From the original pollen grain two sperm nuclei develop within the pollen tube. When the tube has reached the egg nucleus, one of the sperm nuclei unites with the egg nucleus and forms a single cell. The union of these two nuclei is called fertilization. The cell formed by the union of the egg nucleus and the sperm nucleus is called a fertilized egg. The fertilized egg develops into the embryo, or seed, of a new bean plant. After fertilization the petals of the flower fade and fall off. They have served their purpose and are no longer useful.

Seeds develop only after fertilization

There are several ovules within the flower, as shown in Fig. 118. Each will develop into a seed, provided the egg nucleus within the ovule is fertilized. If fertilization does not take place, there can be no seeds. You may find within a pod spaces for seeds in which no seeds developed. Look at Fig. 119. The seed is missing because the ovule in that position was not fertilized. The seed which forms is dry when ripened and is surrounded by a thick seed coat. The tiny embryo will develop into a new plant when the seed sprouts. After the seed sprouts, the food which is stored about the embryo will keep it alive until the young plant has time to set roots in the soil and spread green leaves to the sunshine.

A seed contains the embryo of a new plant

This is the life cycle in a bean plant. The cycle of growth of the tiny embryo — from a seed to a fully developed plant and the production of new seeds, each of which contains a tiny embryo — is a succession of events that takes place in plants during the growing season of every year. The seed sprouts in the warm soil of springtime, grows into a mature plant, and develops more seed before the cold of winter comes again. The embryo in the seed remains alive even though it is exposed to extreme cold.

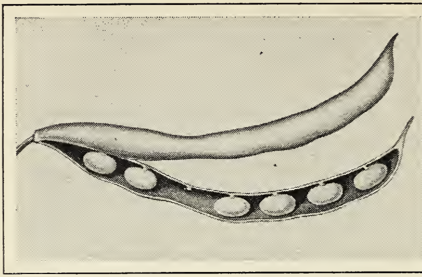


Fig. 119. Seeds develop after Egg Nucleus in Ovule and Sperm Nucleus from Pollen have Combined

There were seven ovules at the base of the flower. One was not reached by a pollen tube

Fig. 120. Bulbs are Short, Thick Rolls of Leaves in which Food was stored during the Previous Summer

A similar life cycle runs in other plants. Trees and shrubs live through the winter, but growth ceases when the cold of winter comes. Some observations in the classroom will help you to understand how trees and shrubs are affected by the warmth of spring when it comes.

You may gather from the out-of-doors some twigs from willow trees, maple, hickory, or elm. There are no leaves on them, but it is easy to see that they are not dead twigs. Place them in a jar of water in a room that is kept warm throughout the day and the night. The small buds on the twigs may be easily seen. After a few days you may see that the buds are swelling, and in a few more days green leaves appear. The changes which you have observed are similar to the changes that take place outdoors with the coming of spring.

Many plants of the temperate zone live through the winter, but all of them are affected by the change of seasons. You have learned from observation that growth ceases in trees during winter. With the coming of spring, growth begins again. Trees that have shed their leaves grow new ones. Blossoms form, sometimes in great numbers. The flowers on the trees, like the flowers of the

bean, have pistils and stamens. Pollination and fertilization take place in these flowers, just as in the flowers of the bean. In some the pollen is carried by the wind. In others it is carried only by insects. The fertilized ovule, or egg cell, develops into an embryo. Food is stored with the embryo, and thus a seed is formed. The seed vessel develops into a fruit. To the botanist (a person who studies plant life) the bean pod, the apple, and the tomato are all fruits, since all of them develop from the seed vessel and contain the seed.

Fruits are seed vessels

Some plants develop special parts that are not seeds, but from which new plants may grow when conditions are favorable. The white potato is a specialized kind of stem, called a tuber, that is rich in stored food. Each "eye" of the potato is a bud and will, under favorable conditions, develop into a new plant. The sweet potato is a specialized kind of root. It too will develop new plants when planted in warm, moist soil. Bulbs, from which many of the earliest spring flowers grow, are not seeds. As shown in Fig. 120, they are short, thick rolls of leaves in which food was stored during the previous summer. They are able to produce leaves and blossoms before most of the plants which are grown from seeds. Dandelions, spring beauties, hepaticas, and violets, as well as other early favorites, grow from roots produced the year before. They also develop seeds which remain in the ground through the winter, but the plants that appear earliest in spring do not grow from seeds.

The purpose of seeds is to produce new plants. In most plants, however, seeds are produced in great abundance, and comparatively few of them ever develop into full-grown plants. The food stored in the seeds is good for animals as well as for the embryo plant. You know, of course, that the fruits and seeds from plants, including grains, nuts, berries, peas, beans, apples, and others, make up a large proportion of the food that is used by man and other animals throughout the winter.

This growth of plants, with the seasonal production of fruits and seed, is one form of adaptation which enables plants to continue from one season to the next in the temperate zone. The plant grows in summer; and while it grows, it produces seeds, within which life continues until the growing season comes again. The life cycles of plants seem to be fitted to the changing seasons.

Seasonal production of seeds is a form of adaptation

Continuous plant life in the belt of the westerly winds depends upon adaptation to marked changes in temperature. This adaptation takes several forms, all of which are examples of a life cycle.

Can You Answer these Questions?

1. What are some of the physical conditions necessary for plant growth?

2. How are growing plants affected by the force of gravity?

3. What is a seed?

4. Where does a bean plant get the food necessary for growth before the roots and leaves are developed? Where does it get food after roots and leaves have developed?

5. What is photosynthesis?

6. What is the transpiration stream in plants?

7. What part does pollen play in the production of seed?

8. What part does nectar play in the life cycle of some plants?

9. What is pollination?

10. Can you trace the steps in the development of a new plant from the time the pollen grain is deposited on the pistil?

11. What is one of the reasons why some ovules may not develop into seeds?

12. Why does the botanist call a tomato or a bean pod a "fruit"?

13. Is a bulb a seed? Explain.

14. Is the growth of plants with a seasonal production of seed and fruits a form of adaptation?

Questions for Discussion

1. What are some of the things that a botanist may see in a flower but that an artist does not see? Are there some things an artist may see that the botanist does not see?

2. Do you think that the life processes described in this chapter apply as descriptions of plant life in the torrid zone or in the frigid zone? What differences do you think might be found?

3. Do you know of any flowering plants that do not come from seed? What do they come from? Do you know some plants that do not produce flowers?

4. Is the bee the only insect that helps in the pollination of plants? Do you know of any others?

5. Are there any forms of plant life that can live in darkness? that can live without soil? that can live without water?

6. Why does a plant usually die when the stem is broken?

Here are Some Things You May Want to Do

1. If you have a good artist in the class, he may want to prepare some large wall charts illustrating the life cycle of a typical plant. If these charts are well prepared, they might be used by other classes.

2. One grouping used for plants lists them as annual, biennial, and perennial. Look up these words and find out what they mean. Then make a list of some plants in your neighborhood which belong to each of these classes. Display some of these.

3. In winter you may find flowers blooming in a greenhouse or in your classroom. Find the calyx, corolla, petals, stamens, and pistil. On the end of the stamens find pollen cups. See if you can catch some of the pollen on a glass slide. Examine it under a microscope. Is the pollen of different plants alike?

4. Make a special study of the pollination of plants. In what other ways are plants pollinated than by insects? Prepare a report and present it to your class.

5. A good story of the life cycle in plants may be found in Kenly's *Green Magic* or McGill's *The Garden of the World.* You will also find Comstock's *Handbook of Common Flowers* of great help in identifying plants you do not know.

6. Have you a school garden during the summer? Do you have growing plants in your classroom during the winter? Both of these offer excellent opportunities for studying the growth of green plants. If you do not have these attractive additions to your school, you may want to form a Garden Committee and be responsible for planting and taking care of some growing plants. Perhaps someone in your class has an older person at home who knows the kind of plants which grow best in your locality. If not, the florist in your vicinity will probably be glad to help you.

7. Not all seeds sprout in the same way. Plant some squash, pea, bean, and corn seeds which have been soaked overnight in water. Note carefully just how the seed begins to germinate in each case. Follow the process for four or five days.

8. Can seeds germinate under water? Place about an inch of soil in each of two tumblers. Plant sunflower seeds in one and pea seeds in the other. Cover the soil in each tumbler with about an inch of water.

9. If you have an aquarium in your schoolroom you will find it interesting to place the seeds of some water plants in it. Collect them in the fall and let them float in the aquarium until they begin to sprout. This may take several months.

10. Grow a number of seedlings in sawdust. Within two or three days after the green plants have formed, carefully remove them from the sawdust. Fasten each one with a pin so that it can rest at the mouth of a test tube with the root inside. Fill one tube with distilled water, another with water in which soil has been shaken, and another with water containing small amounts of dissolved substances such as are found in fertilizers. Compare the rates of growth.

11. What causes a seed to sprout? Collect some seeds which form early in spring, such as elm or maple seeds. Plant some, and keep some dry until the winter and plant them then. Take some seeds from a squash or cucumber and plant some immediately. Keep some dry until the spring and then plant them. Will seeds sprout soon after they are formed? Must seeds be kept from

one season to another before they are planted? May they be kept for many seasons?

12. Fill a small bottle with seeds of wheat or some other small grain. Pour water into the bottle until the spaces between the seeds are filled. Cork tightly and keep for two or three days. Explain what happens.

13. Are seeds "alive" before the root and shoot begin to grow? Can you plan an experiment to show whether seeds use oxygen and give off carbon dioxide before they show any sprouts? to show whether they give off heat?

14. Make a collection of products from your kitchen which are seeds or made from seeds. You might put a sample of each product in a cellophane wrapping and mount them all on a large piece of cardboard.

15. Grow some bean seedlings in sawdust. When the stems are about two inches long, make two lines around the stem about half an inch apart. Use India ink. Observe the rate of growth through an interval of three or four days. Does the distance between the lines change as the plant grows? Explain.

Chapter XI · How do Animals live through the Changing Seasons of the Westerly Wind Belt?

Thus far this story of seasonal change and its effect upon life has dealt with plants. How about its effect upon animals? Do they too change with the seasons? What happens to them during the winter? Do they die or do they live through the cold weather? How do young animals develop? The answers to all these questions make up one of the most interesting of stories regarding the natural environment. As you read it you will appreciate more fully the wonder of the life cycle through which life continues.

With the approach of winter many of the familiar forms of animal life that are so numerous during the summer disappear. Snakes, lizards, and toads hide themselves away in the ground. The insects that are so much in evidence during the summer are not seen out of doors in winter. Some of the birds have flown away. Some of the furry animals of the field and forest have gone into dens to sleep through the winter.

Animal life changes with the seasons

With the return of spring, however, these animals reappear. All forms of animal life become active. The warm sun awakens the snake from its deep, deathlike winter sleep. Birds return from their migration to the south, or come forth from warm shelters in woods or buildings and start immediately to build their nests. Insects appear from the ground or other protected places almost as if from nowhere.

A. What is the Life Cycle of Frogs and Toads?

These activities in the life of many animals of the temperate zone seem to be timed to the seasons. Suppose you follow the life cycle of a common leopard frog through the

seasons. As winter approaches, these frogs go into hibernation. They burrow themselves into the deep mud where it will not freeze. Here they remain until spring. If you could examine a frog during this time, it would be difficult to find any signs of life in it. But when spring comes and the ground thaws, the water gets warmer and the frog comes out from its winter quarters to resume normal activity.

Frogs hibernate

During the month of March in the south and in April and May farther north, you may hear the croaking of the frogs along the edges of ponds and small lakes. It is only the male that croaks. At this time the females are laying bunches of eggs in the water. These the males cover with sperm cells. The egg of the frog is like the egg in the ovule of a flower. The sperm is like the sperm in the pollen of a flower. The egg and the sperm of the flowers unite, and a seed develops from the fertilized egg. Similarly the egg from a female frog and the sperm from a male frog unite, and a new frog develops from the fertilized egg. The union of egg and sperm — that is, fertilization — takes place in the water.

The number of eggs produced by a large female frog may be as many as six or eight thousand. These eggs are arranged in a jellylike mass, as shown in Fig. 121. The number of sperms produced by a single male frog is even greater than the number of eggs laid by the female.

In the spring you can gather some of these fertilized eggs in near-by ponds and swamps. Put them in a jar and take them into your science workroom. If conditions are favorable, the eggs will develop into tadpoles in a short time. A young tadpole resembles a fish, for it has gills for breathing and a tail for swimming. In the water it leads an active life, feeding upon small plants and animals. In the conditions out of doors the tadpole is fully grown in about eight or ten weeks. Legs and lungs develop, and the tail slowly

The life of the frog illustrates a seasonal cycle

A. M. N. H.

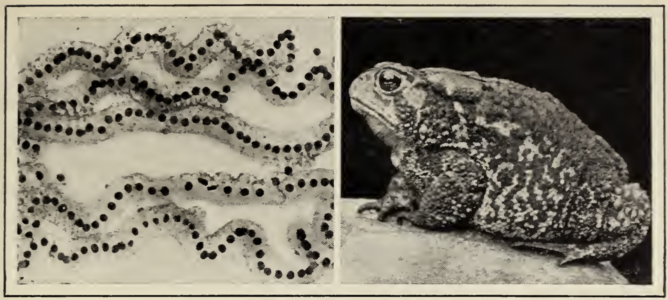
Fig. 121. These are Stages in the Life Cycle of a Frog

The drawings show eggs, tadpoles in various stages of growth, and finally the adult frog

disappears. As the next event in its life it crawls from the water fully equipped to live on land. Some steps in this life cycle are illustrated in Fig. 121. One mass of eggs may hatch into a great many tadpoles.

As a land animal the frog feeds principally upon insects. By the time it leaves the water these are abundant. Its home is in the marshy land along a stream or brook. Frogs are eaten by herons, muskrats, and snakes. With powerful legs, good for jumping while on land and for swimming in water, it is well equipped, however, to escape these enemies. As cold weather comes, the young frog buries itself in the mud to spend the winter just as its parents did the previous winter. Year after year this same cycle of events is repeated.

Toads are somewhat like frogs, but it is easy enough to tell these two animals apart. Contrast Fig. 121 with Fig. 122. The toad's body is covered with "warts," while that of a frog is smooth. The toad is unlike the frog in that it spends most of its time away from the water. It is a familiar animal in the garden and on the lawn. As the cold of winter approaches, the toad crawls into a hole in the ground or under a stone or log, where it hiber-



A. M. N. H. Cornelia Clarke

Fig. 122. How does the Toad differ from the Frog?

Contrast the eggs of the toad as shown in this picture with those of the frog in Fig. 121. Then contrast the adult toad above with the adult frog in Fig. 121. Are there differences?

nates. While in hibernation it seems quite lifeless, but of course it is not dead. When spring comes, it too awakens from its deep sleep and resumes its activity.

As soon as toads leave their winter quarters they move to some near-by lake or pond. No one knows how they find their way to water, but they get there. In the water the females lay eggs and the males lay sperms, just as frogs do. The toad's eggs are held together in jellylike strings. They also differ in appearance from the frog's eggs in that they are blacker. Notice the eggs in Fig. 122. Frogs' eggs are white except for one black spot on them. A female toad may lay as many as twenty thousand eggs, but, like the frogs, the male toad lays many more sperms than the female lays eggs. After the eggs and sperms are laid the toads go back to the gardens and fields from which they came.

In the water the eggs and the sperms unite, and the fertilized eggs develop into tadpoles. These tadpoles develop in much the same way as the frog tadpoles. In a few weeks they change to land animals and crawl out of the water. After they leave the water they move away

from it and spend the remainder of the summer on dry land. When winter approaches they, like their ancestors, crawl into a hole or make one under a stone or a log. There they remain in hibernation until spring comes. Here, then, is another example of life processes going on through the seasons.

Toads, frogs, salamanders, and a few other animals belong to a group called amphibians. An amphibian is an animal that spends part of its life in water and part on land. Amphibians are hatched in water and live there through a tadpole stage. These animals are cold-blooded. They differ from man and many other animals in that the temperature of their blood is about the same as the temperature of the air or water about them. The temperature of the blood of warm-blooded animals, if they are in good health, changes but very little with changes in temperature. Whether the temperature of the air about a man is ten degrees below zero or whether it is "one hundred in the shade," the temperature of his blood remains at about 98.6° F. The temperature of the blood of an amphibian, however, may be 105° or possibly higher on a hot day. On a cold day it may be nearly (but not quite!) as cold as the freezing point of blood. When these animals hibernate they must find shelter in places where it does not get cold enough to freeze them, for in that case the cells in their bodies would burst. They are not always successful in this, and during unusually cold winters many hibernating animals are frozen to death.

Amphibians are cold-blooded animals

The reptiles are also cold-blooded animals. This group includes turtles, lizards, snakes, and alligators. The reptiles that live in the temperate zone hibernate in winter. Turtles bury themselves in the mud. Snakes and lizards hibernate in holes in the ground or under stones. Some snakes seem to have favorite ledges or "dens" to which they go year after year. Twenty or thirty snakes may hibernate in one den.

B. What is the Life Cycle in Insects?

Let us observe the life cycle in another group of living things, the insects. In the temperate zone these animals, including moths and butterflies, dragon flies, ants, lice, grasshoppers, house flies, mosquitoes, gnats, bees, and many others, are numerous in summer, but few are seen out of doors in winter. There are many kinds of insects. There may be more than a thousand different kinds in your own back yard. Let us study a few of them.

The house fly is one of the worst insect pests, although in many sections of the country it is now fairly well controlled. With the approach of cold weather most house flies die. There are always some, however, that are able to live through the winter by hibernation. With the coming of warm weather these few awaken, and the females lay eggs. You know, perhaps, that the house flies lay their eggs in decaying matter such as garbage and barnyard manure.

A female fly will lay more than a hundred eggs at one time and may lay as many as six or eight hundred in her lifetime. Under favorable conditions the eggs hatch into larvæ in about eight hours. The larvæ are commonly called maggots. They eat of the filth in which the eggs are laid, and in about five days of warm weather change into pupæ. In this stage they seem inactive. They do not eat, but great changes are taking place inside the hardened case which surrounds them. After about four or five days in the pupa stage the fly comes out from the case.

The life cycle of a fly shows four stages

Notice that there are four stages in the life cycle of a fly, illustrated in Fig. 123. These are egg, larva, pupa, and adult. Many insects pass through similar life cycles. In the case of the house fly about ten days pass between the time the egg is laid and the time the fully developed fly leaves the pupa. When the weather is cool it takes longer for these changes than when the weather is warm.

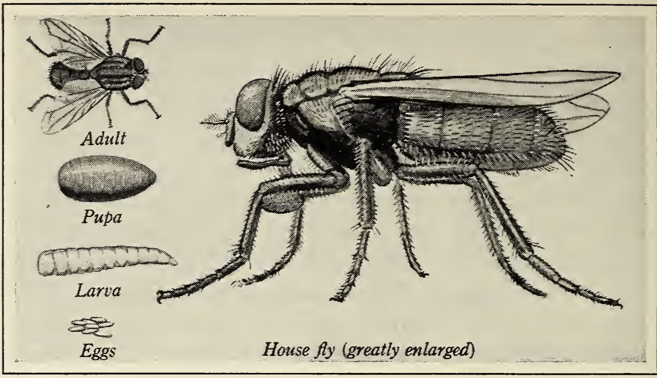


FIG. 123. There are Four Stages in the Life Cycle of a Fly

Illustrated here are the eggs, larva, pupa, and adult fly. Study the much enlarged photograph of the adult fly. How does the fly carry disease germs?

You may wonder why flies are so numerous in regions where they are uncontrolled. A little figuring will answer your inquiry. You may recall that a female fly may lay more than a hundred eggs at one time. Besides, this fly may live long enough to lay eggs four or five times. Let us suppose now that a female fly lays eggs but once, and figure from this the number of flies that would come from the one parent fly that lives through the winter and lays eggs in the spring. Within ten days, if the weather is very warm, each egg may develop into the adult stage. A fully developed fly is about ten days old when it begins to lay eggs. This, together with the ten days required for the changes from egg to the adult stage, makes an interval of about twenty days between the time when an egg is laid and the time when the fly that hatches from the egg is laying more eggs.

Suppose the fly that lived through the winter lays 100 eggs and that half of these develop into males and half into females. Within twenty days from the time the first eggs were laid each of the fifty female flies may lay 100 eggs.

A. M. N. H.

FIG. 124. Flies breed and flourish in such an Environment

Are such conditions necessary?

When these hatch, there are 5000 flies. Suppose that half of these are females and that each of these lays 100 eggs. When these hatch, there will be 250,000 flies. Twenty days later there may be 12,500,000. Thus the single fly may become an ancestor to nearly thirteen million flies in an interval of sixty days. Each of the other three or four batches of eggs laid by a single fly will, if conditions are favorable, result in an equally large number of flies in four generations. Now you may understand why flies become so numerous as the summer progresses.

One fly may be the ancestor of millions

It is not likely, however, that all the eggs that are laid will hatch. House flies are such despised little creatures that effective measures have been taken to control their breeding. In large cities filth — that is, particularly objectionable dirt — that is left uncovered is quickly removed and destroyed. Flies' eggs may be laid on it, but the whole mass is destroyed before there has been time for them to become fully developed flies.

House flies lay eggs in filth

Stable manure furnishes one of the best of breeding places for house flies. It is around farms and in small

communities that control of flies is most difficult. A single manure pile may, in the course of a summer, serve as a breeding place for many millions of flies. A pile of decaying garbage may serve for as many more. Flies also breed in decaying leaves and cloth. In fact, they breed in almost any kind of rubbish. Fig. 124 illustrates some conditions favorable for the rapid spread of flies.

It is easy to see that a campaign to prevent flies must be a campaign to clean up. No amount of swatting will do much good if filth is left about for them to breed in.

A knowledge of the breeding habits of the fly is enough to show how filthy this little insect is. As an adult it feeds upon the foods that we use as well as on filth.

The worst feature of the fly is that it may spread diseases, particularly typhoid fever. The germs of typhoid fever are in the excretions, or discharges, that have come from the body of a person who has the disease. Flies may feed on these excretions and carry these germs from where they fed to the food on our table. It has been shown again and again that cases of typhoid fever are most abundant in the United States during August and September. It is at this same time that house flies are most abundant. It has been proved that house flies may carry the germs of typhoid fever from filth to food.

Flies spread disease

With the approach of cold weather the flies disappear. Most of them are killed by frost. Some will hide away in protected places where they may live through the winter. These come out in the spring and start again to fill the community with millions of their kind.

The mosquito is another objectionable insect. Most of the mosquitoes are killed by frost, but, as in the case of the fly, some will live through the winter. In the early spring the females lay eggs, but, unlike the fly, they lay eggs in stagnant water. The eggs hatch to form the wiggler, or "wiggle-tail." This is the larva. In this form it eats and

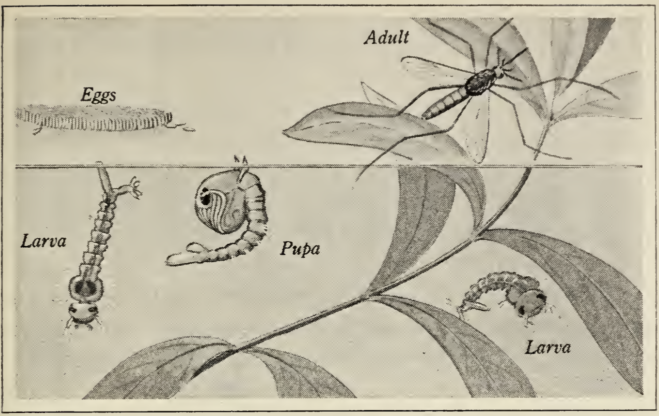


Fig. 125. Here are illustrated Four Stages in the Life Cycle of the Mosquito

Does this illustration help to explain why the different methods for controlling mosquitoes are effective?

grows rapidly. The pupa, the next stage in its development, is an odd-looking creature. The pupa does not eat and is much less active than the larva. From the pupa comes the mature mosquito. It crawls from its case and perches upon it until its wings are dry. It then flies away to enter upon its life work. The life cycle of the mosquito is shown in Fig. 125.

Strange as it may seem, mosquitoes feed mostly upon juices that they suck from plants. It is likely that not one mosquito in a million ever finds a man or any other animal from which it may suck blood. It is only the females that ever attack us, but these quickly leave their plant food to feed upon man when there is opportunity. The males cannot suck blood, for their mouth parts are not constructed so that they can force their way through the skin.

All mosquitoes are objectionable. No one likes any of them. Some forms are dangerous because they may carry

disease. The common mosquito of the northern part of the United States (called *Culex*) is harmless in the sense that it does not carry disease. In the Southern states there is a mosquito which may be very dangerous. This one (called *Anopheles*) may carry malaria. It is not often found north of the fortieth parallel. These two forms are shown in Fig. 126. The malaria mosquito may be recognized by the position of its body while it is sucking blood. There is another that may carry yellow fever. The yellow-fever mosquitoes are common in Central America but are seldom found farther north than the states that border the Gulf of Mexico.

Some mosquitoes carry disease

Malaria is caused by a tiny animal parasite that may live in the blood of man and in the blood of the anopheles mosquito. If this mosquito bites a person who has malaria, she is likely to suck a few of these tiny parasites out of the person along with his blood. These parasites remain alive and multiply in the body of the mosquito. When the infected mosquito bites another person, the first thing it does after breaking through the skin is to force some fluid into the blood of its victim. The parasite may be carried with this fluid into the person's blood, and in this way the person is infected with malaria.

The cause of yellow fever is not so well understood as the cause of malaria, but it is known that the yellow-fever mosquito will carry it from one person to another.

The prevention of malaria and of yellow fever is through control of mosquitoes. The common culex, although it does not carry disease, is so objectionable that it too should be controlled. Mosquitoes breed in stagnant water (not in running water). It is obvious that the way to control mosquitoes is by draining swamps and by removing tin cans and other containers in which water may stand after a rain.

Cold weather brings an end to the torture from mosquitoes. Most of them are killed, but some will live

Fig. 126. The Bite of Either of these Mosquitoes is Annoying

The bite of one, however, may have far more serious results than the bite of the other. Do you know which one? Do you see any differences between them?

through the winter and lay eggs in the spring. They multiply so rapidly that the few who are left soon fill the marshes with great swarms of them again.

Many insects are useful

Not all insects are harmful. Some are very useful. Bumblebees, honeybees, ladybird beetles, dragon flies, praying mantes, and silkworms are among those we consider useful. Without the bees many flowers would fail to produce seeds; for, as you know, the bees carry pollen. The importance of the bumblebee is well illustrated when we realize that without this insect there can be no red clover and no kidney beans. Ladybird beetles, dragon flies, and mantes live upon other insects and help in keeping them under control. Silkworms produce the thread from which fine dresses are made.

The life history of a bumblebee seems even more complex than that of a house fly or a mosquito. It shows, too, a definite adaptation to the changing seasons. The stages in this life history are shown in Fig. 127. During the summer the nest is a busy place, with drones, workers, and queens. Cold weather kills all these except the queens, and these protect themselves by hibernation. A common place for a queen to hibernate is in a rotting log or stump. She crawls into a tiny crevice as far as possible. In this

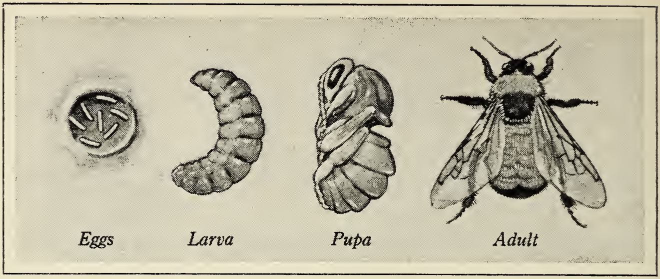


FIG. 127. These are the Stages in the Life of a Bumblebee

way she secures protection from the cold and also from hungry little mice and moles. This queen bee seems entirely lifeless during the winter months, but when spring comes she leaves her hiding place and seeks a place for a nest.

The place selected is usually a hole in the ground. The queen bee immediately builds in her nest some irregularly shaped cells. These are composed of pollen and honey which she has gathered from flowers. She next lays some eggs in these cells. The eggs hatch into larvæ, and the young larvæ feed upon the pollen and honey stored in the cells. But the stored food is not sufficient, and as the larvæ grow the mother is kept busy supplying them with additional food. They pass through the larva stage and into the pupa stage. Now they do not eat, but while in their pupal cases they change to the adult stage.

A colony of bumblebees begins with one, the queen

The task of feeding these first larvæ is almost too heavy for the lone mother. It seems that they do not get enough food, for these first bees are smaller than their parents. In addition, they do not develop sex cells. The bees of this first brood are really undeveloped females. These are called workers, and they spend their lives gathering honey and helping with the work about the nest. The queen bee continues to lay eggs, and with the help of these workers some

In each bee colony there are workers, drones, and queens

FIG. 128. **A Nest of Bumblebees includes Workers, Queens, and Drones**

These three types, as you can see above, differ in size. The nest of bumblebees shown to the right was removed from the ground and placed in a box with a glass cover. **In spite of this change, the bees continued their normal activities**

of the larvæ are well fed. With plenty of food, these may develop into larger bees, some male and some female. By midsummer the single queen that lived through the winter is parent to a large colony. The males are drones. Compare the size of the queen and drone in Fig. 128. The drones gather food for themselves, but they do not work for the colony. The workers are undeveloped females, and these divide the work of the nest, some doing one thing and some another. Some of the young queens may lay eggs and thus add to the population of the nest.

The work of the summer season is a work of building up the colony. But the colony does not last long, for the season is soon over, and when frost comes the workers and the drones are killed and the queens go into hibernation to sleep through the winter. Each spring and summer season brings the same round of events. A lone queen builds her nest, rears her young, and builds up a colony, all of which is destroyed by the cold of approaching winter.

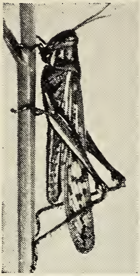


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FIG. 129. Grasshoppers lay Eggs in the Ground

FIG. 130. The Praying Mantis lays Eggs in Masses attached to Small Twigs

FIG. 131. The Japanese Beetle lives through Winter in Larva Stage

Most adult insects die in cold weather

Most adult insects are killed by cold weather, but since the insects of one summer are like those of the preceding summer, it is obvious that insects must live through the winter in some form or other. Grasshoppers similar to the one in Fig. 129 lay eggs in the ground before the winter comes. The adults are frozen, but their eggs hatch the following spring.

Some insects lay eggs in which life continues through the winter

The praying mantis, shown in Fig. 130, is a large insect that looks something like a grasshopper with a long neck. Like a grasshopper it lives through the winter in the egg stage. The females lay egg masses about the end of September. These are attached near the ground to small twigs. Soon after they have finished laying eggs they die, as do all the other adult mantes. In the warm springtime the eggs hatch, and mantes like those of the season before appear. These life cycles are timed to the seasons.

Most insect larvæ are soft-bodied creatures that would certainly freeze in the cold winters of the north if left exposed to them. Some of these live deep in the soil and so they are safe. The Japanese beetle shown in Fig. 131 is an interesting example. After an active summer spent

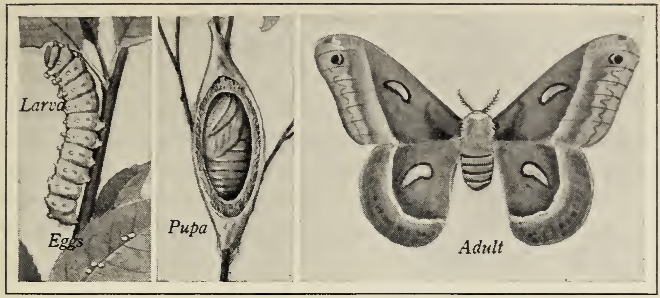


Fig. 132. Do you recognize these Stages in the Life Cycle of the Cecropia Moth?

in chewing up the leaves of much of our most valued vegetation, the female beetles lay eggs in the soil. The eggs hatch in the fall, and the larvæ begin to grow, living chiefly upon grass roots. The larvæ remain inactive during the winter months but resume eating as soon as the soil becomes warmer. In the spring the larvæ turn to pupæ, and the adult beetles appear about the end of June. These beetles, as well as several other undesirable imports from foreign countries, unfortunately for us, seem well adapted to live through our seasons in the United States.

Most butterflies and moths spend the winter in hard, tough pupa cases. You are doubtless familiar with some of our larger cocoons or butterfly chrysalises. The life history of the Cecropia moth illustrates an interesting adaptation.

Some insects live through the winter in the cocoon stage

On one of your winter hikes you may notice, attached to a twig, a cocoon about as long as your middle finger and somewhat thicker near the center. Have you ever seen one similar to that in Fig. 132? The cocoon has a thick brown silk covering which is so tough that it is difficult either to tear or break it. If you take it home and save it until spring, if possible in a box out of doors, you will probably

discover some day a splendid big brown moth decorated with robin-red spots. The female of such a moth will lay about 150 to 200 eggs.

When the eggs hatch, tiny green caterpillars appear. These start eating leaves immediately, and continue to eat until their skins are so tight that they split right down the back. But there is another skin already grown under the old one. This one can expand to a larger size than the first one. The caterpillars continue to eat and shed their skins until they are a little thicker than a lead pencil and about three inches long. Then they stop eating, crawl to some convenient twig, and begin spinning a cocoon. When a caterpillar has surrounded itself with silk to the proper thickness, it sheds its last caterpillar skin and becomes a pupa. Here it rests until spring, when it comes forth as a fully developed moth. The stages in the life of a Cecropia moth are shown in Fig. 132. Some moths and butterflies have two generations in a single year, one which lives and dies in summer, and another which spends the winter in the pupa stage.

At least two of our larger butterflies spend the winter as adults. The monarch, or "milkweed butterfly," migrates just as do many birds, while the "mourning cloak" lives in sheltered places around hollow logs or within cabins, sheds, or barns, where the conditions may be less severe than out in the open.

C. What are Some Other Forms of Animal Adaptation to Seasonal Changes?

You have learned from your own experience that one big difference between summer and winter in the temperate zone is in the amount of animal life which may be observed. In tropical lands animal life is always present; in temperate lands it is most numerous during the spring and summer, becoming scarce during the cold weather.

A very natural question arises from these observations. What happens to larger animals as cold weather approaches? From your study of the life cycle of frogs, toads, and insects you have already learned how these live through the changing seasons. Many other forms of animal life, however, such as different kinds of birds and squirrels, the woodchucks, and other more familiar types, also seem to become scarce during the winter months. What happens to them?

U. S. Bureau of Biological Survey

FIG. 133. The Arctic Tern flies Some Twenty-two Thousand Miles Each Year

Where do the birds go? Many that live through the summer in the frigid and temperate zones meet the change of seasons by migration. As winter approaches, the migrating birds move southward. When winter has passed, they return again to their northern homes. Soon after returning they begin the work of nest-building.

Many birds migrate

Birds are remarkable travelers. There are some that travel as far north as the arctic circle. The nest of the arctic tern has been found within eight degrees of the north pole. This bird, pictured in Fig. 133, nests and rears its young in a region where the summer sun does not set. Then as the long arctic night approaches, it starts a journey southward that continues beyond the antarctic circle. It migrates from the Land of the Midnight Sun in June and July to the Land of the Midnight Sun in December and January. The shortest distance between its January and July homes is about eleven thousand miles. This greatest

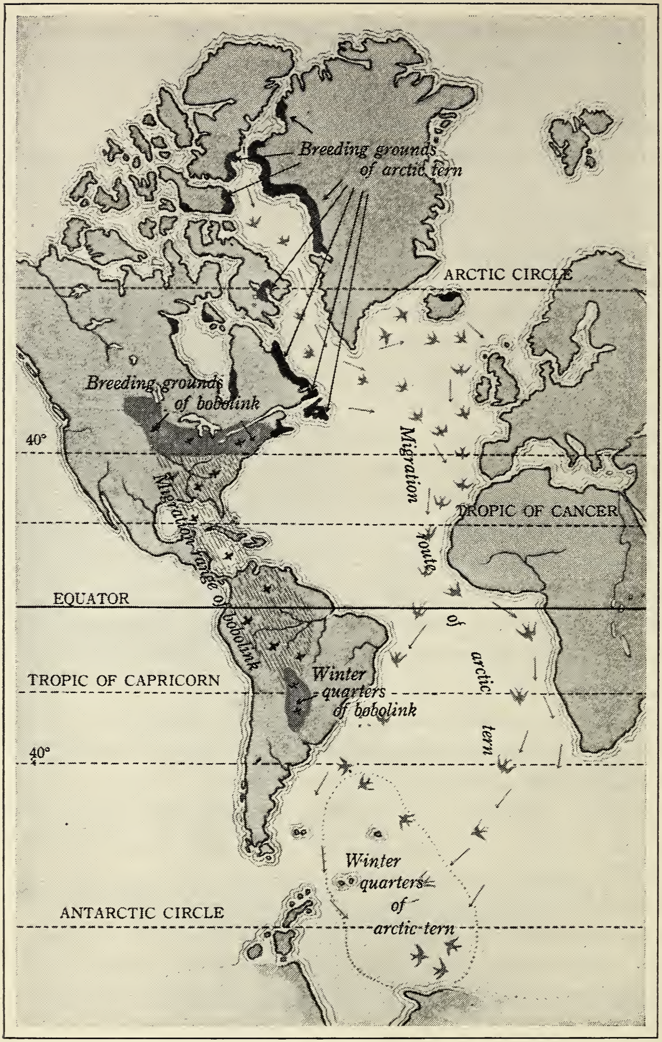


Fig. 134. The Migration of Birds often carries them over Enormous Distances

Do you know the routes of any other birds?

U.S. Bureau of Biological Survey

Fig. 135. Have you ever seen a Flock of Migrating Birds such as This?

of bird travelers flying over land and water travels some twenty-two thousand miles each year, as you can see from the map in Fig. 134.

The bobolink nests in northern United States or southern Canada. In its trip to the south the bobolink travels along the Atlantic coast line to Florida, from Florida to Cuba, and from Cuba to South America. In the Southern states it feeds upon rice and is known there as the "rice bird." Having reached South America, it continues its journey across the equator to the valley of the La Plata River in southern Brazil.

The tern and the bobolink are not the only travelers. The month of September finds the cuckoo, nighthawk, tanager, vireo, kingbird, wood thrush, and many other birds on the way to warmer climates.

Those of you who live to the south of the summer homes of these birds may watch them as they pass. Sometimes

they may be seen in enormous numbers. Some make frequent stops, while others fly for great distances without stopping. Some go by day, but many fly by night. You may see the birds on moonlight nights as they pass between you and the full moon. A good field glass brings them out clearly. A careful student of birds reports that he once counted 262 birds that flew across the face of the moon between the hours of eight and eleven. The birds were probably just as numerous throughout the sky as they were in the circle outlined by the moon. This observation gives some notion of the number of birds that migrate with the change of seasons. Perhaps you have seen flocks similar to the one illustrated in Fig. 135. Not all birds migrate, and some, like the robin, migrate for only short distances. The bird population in the temperate zone in winter is, however, greatly different from the bird population in summer.

The animal upon which the human race is most dependent for food is the cow. The cow is a mammal. She gives milk to nourish her calf, but she gives it in such abundance that there is enough to furnish the human race with milk, butter, and cheese. There are some other mammals, including camels, goats, and sheep, that contribute to the milk supply of man. The mammals are that group of animals that give milk to feed their young. This group of animals includes man, cattle, horses, dogs, cats, raccoons, foxes, skunks, woodchucks, squirrels, mice, and many others.

Man protects domesticated animals through the winter

Many mammals are domesticated because man has found them useful workers or desirable pets. These domesticated mammals are protected by man from the severities of climate. Man does for these animals the preparation that is necessary to enable them to live through the winter. In our study of adaptations to change of seasons we shall turn our attention to the mammals that live out of doors and look out for themselves.

Cottontail rabbits are among the most common mammals of the out-of-doors. Rabbits do not hibernate. They lead an active life throughout the winter. In spring they build a nest, usually in a shallow hole which they dig in the ground. The nest is made of dead grass and warmly lined with fur from the mother's body. The baby rabbits are helpless at birth and must be cared for by the mother until they are large enough to hop about and find food for themselves. Rabbits are extremely numerous because one healthy female may give birth to as many as fifteen or twenty young ones during a single summer.

Rabbits are active throughout the winter

Rabbits feed entirely upon vegetation. Since food is abundant during summer and fall, they approach the winter well fattened and in fine condition. Their fur thickens, too, and when cold weather comes they have a much warmer covering than they have in summer. Winter is, though, a hard season for rabbits, chiefly because their food is scarce. If heavy snows come and cover the ground for long periods of time, many of them die from starvation.

Some animals prepare for winter by storing food. The squirrel is a good example of this type of mammal. Squirrels are active all winter except during the very coldest weather, when they stay under shelter until the cold wave has passed. Their winter homes are in hollow trees. The nests may be lined with leaves and moss, paper, rags, fur, or other soft materials. They store food in the ground or under the shelter of a log near a tree. When food is abundant in the fall, squirrels may work all day and into the night, laying up a winter supply. Is Fig. 136 familiar to you? The hidden store may contain bushels of pine and spruce cones, as well as nuts, acorns, and corn. As you see them in the fall busily at work hiding nuts or acorns here and there in the forest you must know that many of the morsels of food will never be found by the animals that buried them.

Some animals store food for winter

The Children's Museum, Boston

FIG. 136. The Squirrel stores Food for the Winter

Cornelia Clarke

FIG. 137. Do you think the Groundhog is a Weather Prophet?

When spring comes, the squirrels change their food habits. In winter they eat nuts and seeds. In spring and summer they eat twigs, berries, and insects. They also rob birds' nests and eat the eggs. It has been estimated that a single red squirrel may destroy as many as two hundred birds' eggs each season. Their victims include warblers, vireos, thrushes, chickadees, and others. Thus it is obvious that where there are many squirrels there may be a scarcity of these beautiful song birds. In the fall the squirrels go back to their diet of nuts and seeds. In September and October they are again occupied with the task of laying away a store for winter.

The woodchuck hibernates

Woodchucks (sometimes called ground hogs) are hibernating mammals. They feed on vegetation, not always sparing the farmer's beans and peas. During the summer they eat heavily and become exceedingly fat. In September or October they crawl into their dens and enter into the deep sleep of hibernation. They awaken from this sleep in February or March, thin but very much alive again, and begin the normal activities of spring and summer. The woodchuck is well

known as a supposed weather prophet. February 2 is known as "ground-hog day," and the little animal always gets attention in the newspapers on that date. Many people seem to believe that the woodchuck observes the weather on February 2. The animal is shown in Fig. 137. If the weather is clear, so that he sees his shadow, the event forecasts a period of six weeks of bad weather. When this happens, the belief is, he returns to his den for another sleep. If it is cloudy and he does not see his shadow, the animal realizes that the winter has broken and that he need not go back to sleep. How true is this? Without question the belief is merely superstition, for there is no reason to believe that the ground hog knows when February 2 comes round or that he comes out of his hole on that date to study the weather.

Many forms of life show adaptation to seasonal change

What conclusions can you draw from what you have now learned? In summary you may say that all the plants and animals living on land, and many that live in the water, change their manner of life as the seasons change from summer to winter. There are many plants and animals in addition to those you have studied. All these, including tiny creatures visible only through a microscope, the worms, the insects, the amphibians, the reptiles, the birds, the mammals, and others, show special adaptations for living through different physical conditions that come with the change of seasons in the temperate zone.

All of them must have some means of continuing their kind, and each type runs a life cycle of some kind. This cycle follows seasonal change and is a factor in keeping the plant or animal alive through the changing seasons. With the coming of cold weather, life activities in green plants cease and animals become scarce. As warm weather approaches, these life activities start again on a large scale. These changes may be observed by everyone who is willing to make the observations with patience and understanding.

It is needless to say that any time spent in such observations will be more than repaid, for through them one may learn some of the interesting parts of the really marvelous story of life itself.

Living things are adapted to changing seasons. Some individuals live for only a short time, others for a long period of years. All forms of life have some means of continuing which is adapted to their environment and which may be understood by a study of life cycles.

Can You Answer these Questions?

1. What happens to mosquitoes and flies when the cold weather approaches?
2. What differences are there between a tadpole and a full-grown frog?
3. What differences are there between a toad and a frog?
4. What is the difference between a cold-blooded animal and a warm-blooded animal?
5. Can you describe the stages in the life cycle of a toad or a frog?
6. What is the life cycle of a common house fly?
7. In what way is the fly a dangerous insect?
8. Is the life cycle of a mosquito different from that of a house fly? In what ways?
9. Do all mosquitoes carry disease? Do all mosquitoes bite?
10. How is malaria carried from one person to another?
11. What is the life cycle of a bumblebee?
12. Can you trace the life history of a Cecropia moth?
13. Can you name some of the birds that migrate? Trace on a map the routes they take.
14. What is a mammal? How many mammals can you name?
15. What is meant by *hibernation*?

Questions for Discussion

1. Compare the processes of respiration and circulation in animals during hibernation with these processes during active life.

2. Which do you think is more dangerous to man, the fly or the mosquito? What evidence do you have to support your answer?

3. Name some of the different ways in which animals prepare for winter. Can you give examples of each of them?

4. A health officer once said, "The presence of flies is a reflection upon the cleanliness of the people who live in any community." What do you think?

5. One part of the work done in mosquito control is to pour oil or kerosene upon stagnant pools of water. In what ways do you think this helps? Turn again to Fig. 125.

6. What methods would you use if you wanted to study the habits of the migrating birds in your locality?

7. Do you think there are any hibernating animals in the tropics?

Here are Some Things You May Want to Do

1. Prepare a list of rules for the control of mosquitoes, flies, and other insect pests. If your list is a good one, it might be copied and distributed to the people in your community.

2. In the early spring, see if you can find some frogs' eggs. Bring them to class and put them in an aquarium, or glass jar. Observe their development. Observe also the development of frogs in a pond in the out-of-doors. Is this development as rapid indoors as outdoors? You may want to record your observations in a booklet called "The Life of a Frog."

3. Make a collection of cocoons for your classroom. Do any of them develop into insects?

4. How well do you know the animal and bird life of your region? Do you know ten insects? ten wild animals? ten birds? How does each one live through the winter? Do they use the same food through the different seasons? Do you find winter birds that are not found in your community in summer?

5. The boys and girls in one school organized a "Mosquito and Fly Control Squad." They inspected their community to find conditions which were favorable to the development of these insects. These conditions were discussed with the local health authorities and with the people responsible for them. Should you like to try such a piece of work?

6. The map in this chapter shows the migration routes of only a few birds. Perhaps you may like to know about others. See if you can find out about them. Chapman's *Travels of Birds* is a good book. Prepare maps showing the routes of some other birds. You may like to prepare an assembly talk on "Great Travelers among the Birds."

7. On some outline maps indicate the regions in which yellow fever and other insect-carried diseases are now prevalent or were once prevalent. See if you can find out why these particular regions are or were affected by these diseases.

8. Do you want some good books to read? Try some of Fabre's nature books, such as his *Life of the Spider, Life of the Fly,* or *Life of the Grasshopper.* If you read real well, you may want to read parts of Maeterlinck's *Story of the Bee.*

Chapter XII · How are Plants and Animals adapted to Live in Extremes of Heat and Dryness?

A. How did Death Valley get its Name?

Over eighty years ago, in the year 1849, the eastern part of the United States stirred to a magic word, "GOLD!" From distant California came news of gold fields recently discovered. There the precious metal might be easily secured. According to reports nuggets were to be found scattered along river beds. A few spadefuls of dirt might contain untold wealth. News continued to trickle through from the new regions. California became a land of fabled riches. Imagine the results in the East! Thousands of people made hasty plans to leave for the far-off Western coast. They knew little of the hardships of such a trip, but they cared even less. Gold and riches awaited them there! On to California!

There were many routes. Even the shortest of them meant months of weary travel. There were no railroads across the continent and no highways, yet thousands of the gold-seekers started overland across the United States. In spite of the dangers — hunger, thirst, hostile Indians, and even death — long caravans of these adventurers crept along through unknown territory in a tremendous movement. This resulted in expanding the borders of the United States.

Not all the memories of pioneer days are pleasant. Death Valley, in California, is a lasting reminder of the men, women, and little children who died there in 1849 during the mad rush to the California gold fields. Today, automobiles speed across this desert. Then, long trains of wagons creaked along over winding paths through barren sands. The heat of the blazing sun was unbearable.

Death Valley is a stern reminder of the gold-seekers of 1849

The throats of men and animals alike were hot and dry. No trees offered shelter for man or beast. To all appearances this was a limitless desert.

Death Valley is the basin of an ancient lake. This old basin, now the most arid spot in the United States, is influenced by the anti-trades from the south and protected from the westerlies by high mountains on the north and west. The region is more than two hundred feet below sea level. A small river flows into the basin through a deep canyon, but it soon disappears. Much of its water evaporates into the dry desert air, and the rest seeps into the loose sand and rocks. This is one of the hottest regions in the world. A temperature of 120° F. is common, and the Weather Bureau has recorded 134° F. in the shade. Within such desert areas the struggle for life is a struggle with the climate. It is a battle with intense heat by day, often with cold by night, and with extreme drought at all times.

Certain desert lands located in the southern parts of California, New Mexico, and Arizona make up a region called the Great American Desert. Perhaps those of you who live in the East have never known that there is such a vast desert in this country. What do you think it looks like? People who have never seen a desert nor lived near one are likely to think of it as a vast barren stretch of sand extending as far as one can see over a level plain. They think of it as having no plants to speak of and very few animals.

There are both plant life and animal life in the desert

Such a notion of desert life is by no means complete. Certainly there is no dense growth of trees such as one finds in the rain forest or in the forests of the temperate zones. It is equally true that there are few large animals. But deserts are as likely to be rocky as sandy. They are as likely to be hilly or even mountainous as they are to be vast plains or plateaus. More than this, there are many plants and many animals living on desert areas. Some of

Fig. 138. A Desert Environment is not as Favorable to Life as are Some Other Environments

Is there any evidence in this scene from Death Valley to prove this statement?

them may seem strange to you. As you read about them, remember that they are plants and animals definitely adapted to live under the harsh conditions of a desert environment similar to that illustrated in Fig. 138. Let us study some of these special adaptations.

B. How are Plants adapted to live in Hot Deserts?

As you know, every state has some one flower which is usually considered a "state flower," one that stands as an emblem of that state. Some of these are familiar to you, such as the goldenrod, violet, sunflower, rose, apple blossom, bluebonnet, and rhododendron. There is one state flower, however, which is not well known to many, and yet it is one of the most beautiful flowers in the United States. It is the state flower of Arizona, the bloom of the

giant cactus, or saguaro. If you are like many people, you have a rather faint idea of what a giant cactus is like, and none at all of its flower. It grows where few things can grow, and yet it lives from year to year, well adapted to the severe conditions. As you look at Fig. 139, you see the short thick green stem, somewhat like the trunk of a tree. This green stem may be more than a foot thick. A number of smaller branches grow from the main stem. All are covered with spines. The branches are rounded at the ends, and in May the ends are crowned with blossoms, creamy yellow and as large as a saucer. Imagine flowers growing at the tips of a thick prickly stem some thirty, forty, or fifty feet tall!

The saguaro grows very slowly, but may live to be more than a hundred years old. One specimen only eight inches high was known to be sixteen years old. The taller and older ones may be as tall as sixty feet.

But where are the leaves? Suppose you take another look at a member of the cactus family from a position closer to the plant. On the stems are countless short spines or thorns. These are the leaves of the cactus! A close view of these is shown in Fig. 140. Why do you suppose a plant of this sort is better adapted to live upon the desert than one with many broad leaves?

The cactus illustrates an adaptation of plant life to a desert environment

You have learned in your previous science work that plants take in moisture through their roots and lose it by transpiration through the stomata, or openings, in their leaves. An oak tree twenty feet tall may evaporate two tons of water in one day, which means, of course, that it must take in two tons from the soil. Now the cactus too must take in as much water as it loses, but water is scarce in the desert. What is the result? It is obvious enough. The cactus uses carefully what it has!

Persons traveling across the American desert have died of thirst because they could not find any drinking water.

U. S. Forest Service

Fig. 139. The Giant Cactus is adapted to live in the Desert Environment of the Arizona Plains

Frasher's Photo, Pomona

Fig. 140. The Leaves of the Cactus are really Spines or Thorns

In what ways do these help the plant to live?

Carson Studio

Fig. 141. The Barrel Cactus may be a Valuable Source of Water for the Thirsty Traveler

Natives, however, know a rather unusual source of drinking water. In some desert areas another cactus, called the barrel cactus, is found. It looks like a tall green barrel, and that is what it really is — a barrel of water stored against seasons of extreme drought in a land of little rain. Such a cactus is illustrated in Fig. 141. When the experienced desert traveler feels the need of water, he cuts across the stem of a barrel cactus, about three feet from the ground, gouges a hole into the pulp, and waits for the hole to fill with sap.

Notice now how all these peculiar traits of the cactus plants are really a form of adaptation to the environment. Water in the desert is scarce. The cactus, being a living thing, must have water. Further, it must use carefully

what it can get. Because its stem is big and thick and its spines, or leaves, are tiny, less leafy surface is presented to the sun. The process of transpiration takes place more slowly than in leafy plants, for there is less surface from which water may escape. The stored supply lasts longer. The cactus illustrates also several other forms of adaptation to the environment. Because of its spines and thick skin, animals are inclined to let it alone, and its tough coating protects it from extremes of heat. Some cactuses have also a very bitter taste. The taste is an added protection from hungry and thirsty animals.

Perhaps you have cactus plants in your home as house plants. The crab cactus, or Christmas cactus, is an especially pretty one with its mass of red blossoms hanging from the stems in midwinter. It will grow in poor sandy soil and requires little water. It grows best if kept in a warm sunny window, which, of course, gives the conditions under which it would have lived if it had been left in its native home, or habitat.

There are many different forms of plant life in the desert

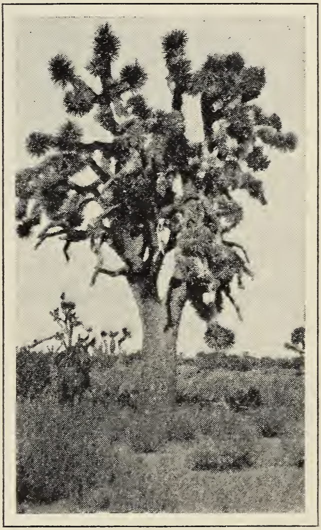
There are many other desert plants. Sagebrush, mesquite, and others grow, bloom, and produce seeds within a few weeks during occasional periods of rain. The seeds may remain upon the hot soil for several seasons before sufficient rain again starts growth. During a short season of rain the ground may be carpeted with yellow poppies and pink desert verbenas. The cactuses, in all shades of pink and yellow and red, are in bloom. Joshua trees, illustrated in Fig. 142, which belong to the lily family, spread their strange shapes against the sky line, and the yucca lily displays a single stiff spire of white bells which may reach twice as high as your head.

You have seen thus far that there is plant life in the American desert and that this life is adapted to its special environment. You may ask, "What about animal life?"

C. How are Animals adapted to live in Hot Deserts?

Many forms of animal life are adapted to live in the desert

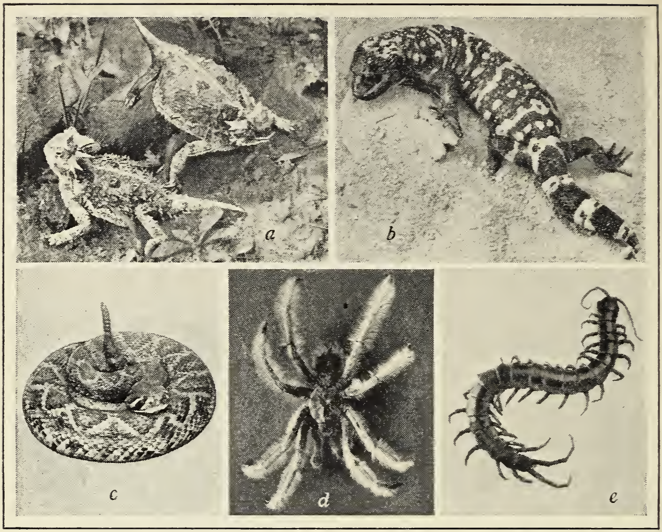
Animals of the desert, including man, depend upon the plant life which grows there. Beetles, butterflies, bees, grasshoppers, locusts, quail and other small brown birds, buzzards, snakes, horned toads, box turtles, and land snails are among the more common animals. There are some mammals, including the antelope, coyote, and jack rabbit. Since all of these are small, they require comparatively small amounts of food and water. If you should examine a number of giant cactuses you would be sure to find holes in the sides of the stems, made by desert woodpeckers. They build their nests in the cactus stems just as the woodpeckers of the forest build their nests in tree trunks.



U. S. Forest Service

Fig. 142. The Joshua Tree, which belongs to the Lily Family, grows in a Desert Environment

None of these forms of life is entirely strange to you. There are some, however, which are peculiar to a desert environment. Have you ever seen a horned toad? Look at Fig. 143, *a*. You may have read stories about these little animals and how they have lived for years incased in cement without food or water. One was said to have lived for forty years in the corner stone of a building where even the supply of air was limited. These stories are exaggerated. They are based upon the fact that desert animals can live where other animals could not live.



a, b, e, A. M. N. H.; *c*, F. M. N. H.; *d*, U. S. Bureau of Entomology

Fig. 143. Many Forms of Animal Life are found in the Desert

a, horned toads; *b*, a Gila monster; *c*, a rattlesnake; *d*, a tarantula; *e*, a centipede

The horned toad is not really a toad at all but a lizard. Its skin is tough and leathery. It can endure drought and heat as no kind of toad possibly could. It eats insects of many sorts. It is protected by its color, so that it cannot be seen among the sand and bushes except at close range. When caught it will pretend to be dead and flatten out on the ground like a flat stone. If really angry it will stick up its horns and throw out from glands near its eyes a stream of red liquid which blinds its enemies long enough usually for it to make good its escape. Its young are born alive and at birth are fully able to protect themselves.

The horned toad is not poisonous, but there are other desert creatures not so harmless. There are at least three different kinds of rattlesnakes. These, as you know, are among the four poisonous snakes in the United States.

They are easily distinguished by the so-called rattle at the tip of the tail. Look at Fig. 143, *c*. The number of joints in the rattle is popularly believed to indicate the age of the snake. This is not so, however, for each time the snake sheds its skin a new ring is formed on the rattle. Sometimes shedding takes place more than once in a year. Sometimes the rings break or fall off. The number of rings, therefore, is not an accurate way of determining the age of a rattlesnake.

Rattlesnakes are poisonous

There are other forms of desert life which are harmful. Among them is the Gila monster, a large lizard which sometimes reaches a length of two feet. From Fig. 143, *b*, you may feel that the title "monster" is a good one. There is the tarantula, a large spider which paralyzes its insect and other animal food by a poisonous bite. Fearful stories have been told about the deadly tarantula, but its bite is not deadly to human beings. It is, however, extremely painful. It produces an effect similar to a bee sting, but worse. In Fig. 143, *d*, is a picture of a tarantula. Another strange inhabitant of this desert area is the centipede, illustrated in Fig. 143, *e*. It too has a poisonous bite which is dangerous to man.

This description of plants and animals in the American desert shows that life may be adapted to an environment which seems unfavorable. It is an environment in which plants and animals common to the more moderate parts of the temperate zone could not live.

In the deserts of Africa, Asia, and Australia there are other examples of adaptation to an environment of extreme heat and drought. The camel, although not a native of the American desert, is a familiar animal in the deserts of Africa and Asia. It is fitted for life in the desert in many interesting ways. It can eat prickly plants because its lips are hard and calloused. It can close its nostrils and thus keep out the blowing sand. Its eyes too are adapted

The camel is adapted to live in the environment of the desert

to keep out the sand. Its cushioned feet protect it from the hot earth. Its tough, thick skin protects it from both sand and heat. It has a peculiar stomach adapted for storing water. One drink every three to five days is enough. The hump on its back is really a storehouse of fat which it can draw on when food is scarce. A camel may travel with its load about twenty-five miles in one day. With water stored in its peculiar stomach and fat stored in its hump the camel is a most useful beast of burden on the desert.

D. What is the Climate of the Desert?

From these scenes of desert life what should you say are the main points of contrast between such an environment and that of other lands as you know them? Are there differences in temperature? rainfall? seasons? Let us summarize some of these differences.

The most outstanding point of difference is probably found in the rainfall of the regions. In the tropics heavy rains are frequent. These are not evenly distributed throughout the year, as in the westerly-wind belt. When they do fall they are so heavy that seasons in the tropics are called the rainy season and the dry season.

Differences between life in the desert and life in other regions are largely due to differences in rainfall

How about rainfall in desert regions? In some of them there is no rainfall for a long period of time. In some parts of the Sahara rain sometimes does not fall for several years. The region, therefore, is one of extreme dryness. In some parts of the American desert region there is an even distribution of rainfall, but this is very slight when compared with regions in the westerly-wind belt and in the belt of equatorial calms.

Perhaps some figures will help to show these contrasts more clearly. In the following table is given the average rainfall for each month over a long period of years at three points located in different regions. Indianapolis is a typical

city in the westerly belt; Yuma, Arizona, is in the region of the Great American Desert; and Iquitos is near the equator in the western part of South America.

	Indianapolis	Yuma	Iquitos
January	3.0	0.4	10.2
February	3.1	0.5	9.8
March	4.0	0.4	12.2
April	3.4	0.1	6.5
May	4.0	—	10.0
June	4.2	—	7.4
July	4.1	0.1	6.6
August	3.2	0.5	4.6
September	3.0	0.2	8.7
October	2.7	0.2	7.2
November	3.5	0.3	8.4
December	3.0	0.4	11.5
Totals	41.2	3.1	103.1

Do these figures show any contrasts in rainfall in these various regions?

The temperature too of desert regions differs in many respects from those of the westerlies and the tropical regions. As you would expect, the temperature generally is much higher in the desert than it is in the region of the westerlies. The average temperature at Indianapolis over a long period of years is about 57.1° F., while at one point in the Sahara Desert it is 76.6° F., a difference of almost twenty degrees. It is not true, however, that the desert is uniformly hot. The temperature over a period of a year in the desert may range from the coldest to the warmest month almost as much as it does in the temperate zone. Thus the difference between the coldest and the warmest month at Indianapolis is about forty-seven degrees. At one point in the Sahara Desert it is about forty-four degrees, and at Yuma about thirty-six degrees. Thus the desert has comparatively cold months and comparatively hot months.

One striking difference between the desert regions and the westerly belt, however, is the tremendous range in temperature during the day. In Indianapolis and other

cities of the westerly belt a warm day may be followed by cooler nights, but the differences between day and night are not really so great. A change of twenty degrees between day and night in the westerly belt may be typical. In desert regions, however, such a change would be a small one. Sometimes the evenings may bring frost and the days be unbearably hot. At one point in the Sahara a temperature of 59° F. was recorded at sunrise, while at 2 P.M. the temperature was 116° F. The reason for this extreme daily range in temperature may easily be explained. The rays of the sun heat the sand and rock of the desert very rapidly. The heat is not held for long. As soon as the sun sets, the surface quickly cools and the temperature drops.

Extreme changes in daily temperature are common in desert regions

Desert regions, then, present conditions far different from those in the westerly-wind belt and in the equatorial regions of the torrid zone. Plants and animals must be adapted to long periods of drought and, even under the best of conditions, to little moisture. Further, they must be adapted to extreme daily changes in temperature.

Life in the desert is a problem of adjustment to conditions of extreme heat and little water. Animals and plants adapted to live in the desert are quite unlike the animals and plants adapted to live in the well-watered agricultural regions of the westerly-wind belt.

Can You Answer these Questions?

1. Why is Death Valley a desert region?

2. In what ways is the giant cactus well adapted to life in the desert?

3. Why are desert regions of the north temperate zone mostly south of the thirty-fifth parallel?

4. How many different ways do you know in which animals are adapted to a desert environment?

5. Does the number of rattles on a rattlesnake tell its age? Explain.

6. In what ways is a camel adapted to desert life?

7. What are the main differences in the environment of the desert, the westerly-wind belt, and the equatorial regions?

8. How can you explain the great differences in temperature between day and night which sometimes occur in the desert?

Questions for Discussion

1. Why are April, May, June, and July the driest months in Yuma, Arizona?

2. Suppose a giant cactus had flat stems instead of round stems. Could it be as successfully adapted to the environment of the desert?

3. What plants other than the cactus do you know that have needles and thorns rather than smooth broad leaves? In what manner do the thorns of other plants illustrate adaptation to environment?

4. What is your own state flower? Do you know anything about its life cycle?

5. Does a rattlesnake always rattle before it strikes?

6. Why, do you think, are there no camels on the Great American Desert?

7. Do you think that the desert regions of the world can ever become regions of high civilization?

8. What is the treatment for the bite of a poisonous snake such as the rattlesnake?

Here are Some Things You May Want to Do

1. In this chapter you find references to the cactus, the yucca, the Gila monster, the rattlesnake, and other plants and animals of the desert. See what you can find out about the life cycles of these. Use encyclopedias and prepare a class report on your findings.

2. Prepare a paper giving information concerning your own state flower. Try to answer such questions as When does it bloom? Does it grow from seed? How often does it bloom? What kind of environment suits it best? You might like to illustrate your paper with the proper drawings.

3. Here are some stories you might like to write and read in class:

Life on a Banana Plantation
A Trip across the Great American Desert
The Lure of the Tropics
Life on the Roof of an Equatorial Rain Forest
With Camel Caravan through the Sahara

4. Prepare a class paper on "Some Strange Animals that live in the Desert."

5. Prepare a list of books and magazine articles that can be obtained in your library on some of the following topics:

Life in the Jungle
Life in the Desert
Life in the Tropics
The Forty-niners

Chapter XIII · How do Living Things adapt themselves to Life in the Ocean and along the Shore?

What do you know about life in the oceans, those great bodies of water that cover more than half the surface of the earth? A map shows large areas of water extending from the cold regions of the north to the cold regions of the south. In the frigid zones these ocean waters beat against polar ice caps throughout the year. In the torrid zone the ocean shore is always warm. What a difference there is between the extremes pictured in Fig. 144! Yet the physical conditions in the waters of these zones vary much less than they do on land.

The very small amount of water in the desert and the extremely heavy rainfall of the tropical rain forests represent two of the extremes of physical conditions on the land. In the ocean, of course, the water supply is always the same.

The physical conditions in the ocean are very different from the physical conditions on land

On land the extremes of temperature are another determining factor of physical conditions. The extreme range is from an occasional $-90°$ F. in northern Siberia to an occasional 130° F. in Death Valley, or a range of two hundred and twenty degrees. In the open ocean the lower limit cannot be below that of freezing, which in the case of salt water is about 30° F.; the upper limit is about 80° F. Thus the range of temperature in the sea is about fifty degrees, while that on land is more than four times as great.

In other ways conditions in the sea are more nearly uniform than on land. The change in temperature in sea water during twenty-four hours is very little. On land it is always considerable, and in the extremes of the desert the daily range may be from the temperature of freezing to 100° F.

In the sea with its narrow range of physical conditions there are fewer kinds of plants and animals than on land. The number of individual plants and animals in the sea is enormous. The sea is thickly inhabited from north to south and from the surface downward to great depths. Such extremes as there are in the sea, then, are between the frigid and the torrid zones and between the surface and the great depths.

A. What are the Conditions of Life along the Seacoast in the Frigid Zones?

The Arctic is a water area; the Antarctic, a land area

The effects of water on physical conditions are illustrated by a comparison of conditions within the arctic and antarctic circles. Look at the maps in Fig. 145. The Arctic is mostly sea, and during the long summer period of daylight there are vast areas of open water with an abundance of living things. Small swimming and floating forms are frequently so abundant that they color the surface of the water.

The Antarctic, on the other hand, is mostly land surface with high mountains. The climate is much more severe in the Antarctic. There are no land animals except a few forms that live along the shore of the sea and take their food from it.

There are no land animals away from the seacoast of the Antarctic

One of the few visitors in this cold and barren land of the south is the penguin. This bird, unable to fly, is a powerful swimmer, feeding upon fish and other forms of sea life. It comes on shore to lay eggs and hatch its young. The penguin is a helpless bird. It nests in regions where there are no land animals to eat the eggs and destroy its young. It finds safety in the antarctic shore, for no four-footed animals are found there. No other animal is adapted to live through such severe physical conditions as are endured by the emperor penguin. Several of these birds are pictured in Fig. 144.

Fig. 144. There are Tremendous Differences between the Environments of the Frigid Zones and the Torrid Zone

How many differences can you find and explain? (Upper picture from *The Last Continent of Adventure* by Walter B. Hayward. Courtesy of Dodd, Mead and Company)

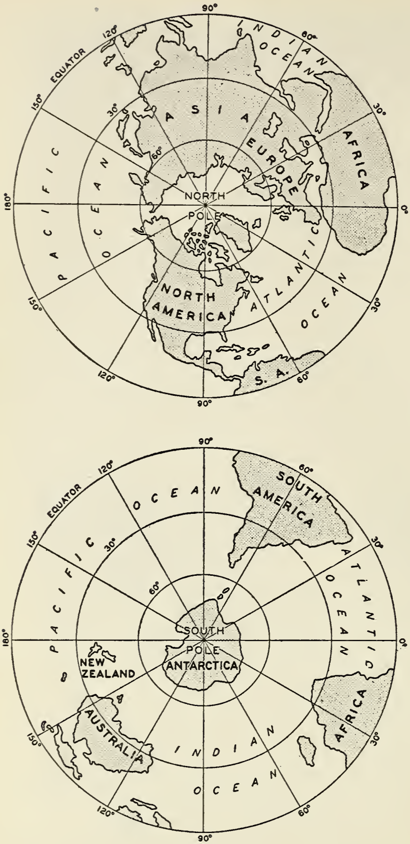


Fig. 145. The North Polar Area is largely a Water Area. The South Polar Area is largely a Land Area

What effect does this have upon the types of living things found in each area?

They nest in winter in the severest cold of antarctic darkness, with the temperature about them frequently as low as $-60°$ F. The young when hatched are helpless and must be cared for by their faithful parents. By late summer (January in the Antarctic) the young are able to swim about and hunt food for themselves. They make for the open ocean, there to remain until the breeding season comes again.

There are no permanent human inhabitants in this southern region of cold, south of the sixtieth parallel. By way of contrast it may be interesting to know that there are more than a million people living as permanent residents in the Northern Hemisphere north of the sixtieth parallel.

The water north of Antarctica, like the water of the Arctic, is rich in plant and animal life. Some large water animals, including seals and whales, feed in these regions.

Donald B. MacMillan

Fig. 146. A Walrus sometimes weighs as much as a Ton

Where does this animal get its food?

U. S. Bureau of Fisheries

Fig. 147. Seals, when undisturbed, develop into Enormous Herds

These animals take large quantities of food from the sea. Do you know what kinds of food they use?

In the more hospitable arctic regions of the north there are many forms of land animals large and small, but many of them depend directly or indirectly upon life in the sea. Walruses, seals, and polar bears live in large numbers along the sea of the north frigid zone.

There is evidence that food is abundant in the fact that the walrus is such a large animal. Some weigh as much as a ton. Look at the size of the animal in Fig. 146. Walruses live in herds numbering from thirty-five to fifty. They feed upon shellfish that live in the mud along the coast. Their large tusks are well adapted for digging their food. Walruses are valuable for oil, for hide, and for ivory. Their numbers have been greatly reduced during recent years by hunters.

There are many forms of animal life in the Arctic

Seals have been extremely numerous along arctic shores. These graceful animals are powerful swimmers. They feed upon fish, shellfish, and sea birds, and in turn are food for the polar bear. They are beautifully adapted to live in the north. A thick layer of fat just beneath their skin is effective protection against the cold. They are able to catch food in

great abundance, and they develop, when undisturbed, into enormous herds. A large herd is shown in Fig. 147. The seals are a chief article of food for the Eskimos. Some kinds are hunted a great deal for fur. Their abundance is illustrated by the fact that well over half a million are caught annually in the north Atlantic.

The abundance of sea life in northern waters makes the Arctic a favorite feeding ground for the biggest of all animals, the whale. The largest ones may weigh nearly a hundred and fifty tons. They are powerful swimmers and travel great distances. What enormous users of energy they must be! The energy which they use is derived from the food they take from the water. The whalebone whales live on small plants and animals which they catch as they swim along on the surface of the water with their mouths open. As much as two tons of small sea life has been found in the stomach of a single animal. Other whales live on larger animals. Seals are the chief food of the killer whale.

The whales are great travelers, moving with the seasons from the polar regions, where they go in summer, almost to the equator. The whaling industry has greatly reduced the number of whales, and some kinds once numerous are now extremely rare. They are most numerous now in the Southern Hemisphere, and during the summers in the Antarctic whale-hunters are most active.

That plants and animals depend on each other is illustrated by life in the Arctic

The polar bear is a familiar animal of the Arctic. This bear feeds mostly upon seals and other animals that live along the coast. Here is an interesting succession of relationships: the polar bear feeds on seals; seals feed largely upon fish; fish feed upon a variety of smaller organisms (living things) that float and swim in the sea; and the food of these smaller organisms comes in large part directly or indirectly from tiny green plants that float on the surface of the sea. The tiny green plants use the energy from the sun's rays and make food from carbon dioxide, water,

and minerals. In the sea as on the land all living things depend directly or indirectly for food upon the energy of solar radiation.

During the long polar nights food is scarce, and many of the animals of the frigid zones swim off to the more hospitable regions of the temperate zones. For the animals that remain and live through the period of darkness the struggle for life is indeed severe.

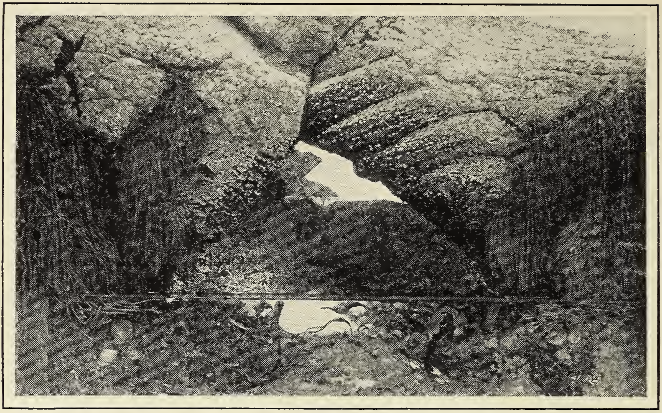
B. What are the Conditions of Life along the Seacoast of the Temperate Zones?

To a careful observer the seashore is not merely a barren stretch of sandy beach and rocks; it is full of life. The water is crowded with creatures. These feed upon one another, and all are interestingly adapted to their way of life. Shore species, or varieties, are exceedingly abundant.

The environment of the seacoast changes twice during every twenty-four hours as the tides rise and fall. The land surface next to the low-water mark is covered most of the time with water. At the edge of the high-water mark there is a region that is covered only during highest tides. The length of time during which the land is covered with water determines the kind of life that is found there.

Life is abundant along the seashore of the temperate zones

The first objects that attract attention on a rocky beach are the barnacles and rockweeds, which are extremely abundant. The barnacles, small sea animals, cover the rocks with their white shells, and the rockweeds form dense beds of vegetation, as shown in Fig. 148. The rockweeds are especially interesting, since many small animals, such as periwinkles and crabs, live upon or under them. Many varieties of seaweeds, sea anemones, barnacles, crabs, and snails live in the cracks and crevices of the rocks. Along some rocky coasts black mussels may be so numerous that they cover the entire surface.



A. M. N. H.

Fig. 148. The Seacoasts of the Temperate Zones are Regions which have an Abundance of Life

Seaweed will be covered when the tide comes in

The numerous rock pools are true natural aquariums, far more interesting than any made by man. In these little sea gardens grow seaweeds and many kinds of animals — sponges, starfishes, crabs, and sea urchins.

On sandy shores the greater part of the inhabitants live under the surface and can be found only by digging for them. They may give evidence of their presence, however, by the open mouths of their burrows or by the jets of water or bubbles of air which they send up. Many species of clams and snails, as well as some crabs, live in this manner. In some places the sand dollars are common. They live buried just below the surface at low-water mark. The wet sand may be covered with the burrows of sand hoppers, which hop along the beach as do grasshoppers in the fields.

Egg cases of many odd shapes and belonging to many different kinds of animals may be found along the beach, where they have been washed up by the waves. The rocky shore and the sandy beach show different things.

On muddy shores the eelgrass often grows abundantly, giving the appearance of a flooded meadow. Many animals live upon or in the midst of this eelgrass. Scallops and prawns are very numerous. Clams, crabs, and worms are also very plentiful in such a region. The fiddler crab, the common edible crab, the hermit crab, and the spider crab are the most common species of mud crabs.

Life along the seacoast is adapted to the effects of rising and falling tides

These animals are adapted to live in different physical conditions, and the physical conditions are determined in part by the rise and fall of the tide. Fig. 148 shows seaweed that will be covered when the tide comes in.

When the tide goes out, land animals follow it, feeding upon the sea life that is left exposed. Birds and mammals come upon the scene in search of food. Of the birds the gulls, the terns, and the sandpipers are most numerous in the temperate zone. There are many mammals that feed along the shore, including raccoons, minks, and skunks.

C. What is the Character of Living Things in Shallow Water?

In the water beyond the range of low tide is a population entirely different from that left exposed when the tide goes out. In all the climatic zones there is an abundance of near-shore life. It is probably most abundant along the shores of the warm tropical seas. Figs. 149 and 150 illustrate some of the kinds of life to be found in the Caribbean Sea. The ocean bed in the shallow waters of this region is like a flower garden. In its natural setting it is a display of a great variety of colors, including purple, red, orange, violet, and green, all blending into a glimmering mass. Yet there is not a flower, not even a bit of seaweed in the entire picture!

Life is abundant in shallow tropical seas

The things that look like cactuses, dahlias, and fringed chrysanthemums growing upon thick stems are really

animals called sea anemones. They have no bones in their bodies and are nearly all water, like the jellyfish which are so troublesome to ocean bathers. These sea anemones belong to the group of animals called cœlenterates, or "stomach animals," for their bodies are largely mouth and stomach. A sea anemone when young attaches itself to a rock or a shell upon the bottom of the shallow sea. Its body is a hollow stomach. The upper end, as seen in Fig. 149, is a mouth surrounded by rows of lashing thread-like outgrowths called tentacles. Each one of these contains a stinging poison. A sea anemone has no need to go in search of its food. It simply waits until a small fish or other animal touches the tips of its tentacles. Then the tentacles sting the fish, and the anemone swallows its unfortunate victim through the hole called a mouth.

© Nature Magazine, Washington, D. C.

Fig. 149. The Sea Anemone, which looks like a Flower, is really an Animal

It catches food that comes to it

Notice how the sea anemone is adapted to live in its environment. It is fastened to the rock or some other object and cannot move in search of food. Its construction is such, however, that it can secure its food by merely reaching out for it. It looks like a flower, but it can change its form as can no flower you ever saw. When danger approaches, it pulls in its tentacles and contracts its stem until it is just a small lump of jellylike matter.

Roy W. Miner

FIG. 150. Coral is Common in the Warm, Shallow Waters of Tropical Seas

Representatives of another very common form of life in these waters are the corals, one species of which is shown clearly in Fig. 150. The staghorn corals, in shades of brown, green, yellow, and violet, branch upward for many feet, like some strange hard cactus. The hard substance which gives coral its shape is lime, discharged from the bodies of the little animals that live in it. Perhaps you never realized that coral is a form of animal life. In its native water, however, each small cell houses a tiny mass of living matter — an individual coral animal. Each little animal has its own stinging tentacles and its own mouth and stomach. As new organisms form, each builds its skeleton on that of its parent. In this manner coral reefs are formed. One of these is shown in Fig. 151.

Sponges are familiar animals of the seashore. The common types you use for washing and cleaning are most familiar. There are many others. Some sponges form thin, lacy, fernlike structures which sway to and fro in the gentle motion of the ocean waters. Others look much like the corals. All of them, however, feed in the same way. The

Official Photograph, U. S. Navy

Fig. 151. Coral sometimes grows to form a Coral Reef

water, with its abundant living matter visible only through a microscope, flows through the holes of the sponge. Cells located within these holes take food and oxygen from the water. There are giant sponges weighing more than a hundred and fifty pounds after the water has been evaporated from them.

The sponge is a form of life which gives shelter to many other living things. Close examination of a living sponge reveals that it houses many "star boarders." One sponge, cut into pieces by a group of trained observers, averaged a shrimp to each cubic inch, with an occasional small crab besides. Several minute fish lived within the hollow shelter of its center, using their fins to crawl and climb from tunnel to tunnel. It might accurately be stated that the home of these fish was a living sponge.

D. How are Animals and Plants adapted to live in the Open Sea and at Great Depths?

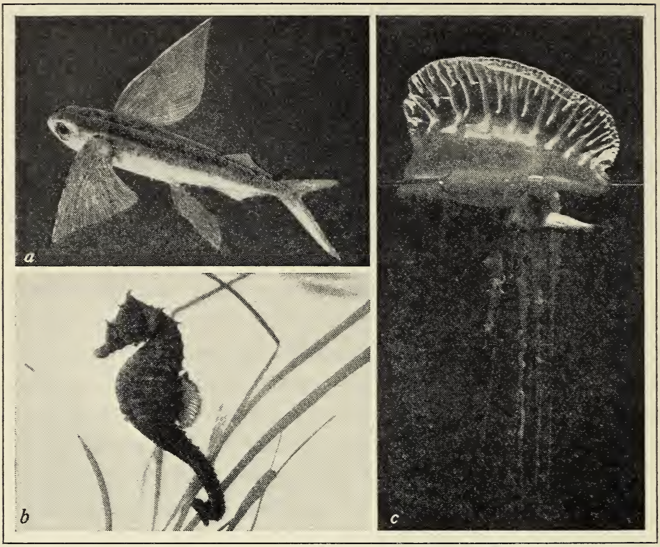
East of the West Indies but west of the Azores and in midocean is a stretch of calm waters known as the Sargasso Sea. In it are large masses of floating seaweed. Strange tales have been told by sailors in all ages about the dangers of the Sargasso Sea. Here, according to accounts, was the home of terrifying sea serpents and other indescribable

monsters. All the floating wrecks of ships which dotted the seven seas were at some time supposed to make their way to the Sargasso Sea, forming a graveyard of disabled abandoned ships. Into these waters, too, ships loaded with men and cargo were supposed to be drawn, never to be released, but always floating in a never ending whirlpool. The heavy seaweed made it difficult to escape. Many stories have been written about this fabled sea. Most of them are nothing but vivid fiction.

The truth of the matter is that most of the seaweed found there grew at one time close to the shores of the Gulf of Mexico or the Caribbean Sea. It has been carried by ocean currents into a whirlpool covering half as much territory as the United States. This stretch of nearly still water is between the waters of the Gulf Stream flowing toward the northeast, driven by the westerly winds, and the ocean current toward the southwest, which is set up in the opposite direction by the northeast trade winds. It is within the region of the horse latitudes, or doldrums. No strong surface currents flow outward from the Sargasso Sea. Therefore seaweed that floats into it is likely to remain there. The seaweed covers about 10 per cent of the surface, but it is not in any place impossible to get through it. William Beebe and other scientists have gone out to study the Sargasso Sea. They never saw a sea serpent, and they found no abandoned ships.

Life in the Sargasso Sea is even more plentiful, probably, than in the warm waters of the Caribbean, for the masses of seaweed, or sargassum, offer both food and protection to the fish and other creatures that live in it.

The weed itself is buoyed up by numerous small air bladders that grow upon its tips. As it gets older and larger, some of the bladders become punctured. During the time of growth the weed has become covered with the shells and skeletons of animals that have lived in or upon it. These too help to make it heavier. Finally, when it is no



A. M. N. H. New York Zoological Society

FIG. 152. Many Strange Forms of Sea Life are found in the Sargasso Sea

a, flying fish; *b*, sea horse; *c*, Portuguese man-of-war

longer lighter than the water it takes the place of, it sinks to the bottom of the ocean. Its total life is probably not more than one year.

The Sargasso Sea is a region of abundant plant and animal life

Fish are especially plentiful in the Sargasso Sea. Many of the larger kinds, such as sharks, find it an ideal home, for there is plenty of food for them there. Many curious types of sea life are found in this region. Look at the "flying fish" in Fig. 152, *a*. It is able to crawl upon the seaweed, swim about in the water, or leap into the air when its enemies become too troublesome. Countless small fish and shrimp can be found. Many of them have the same shade of greenish yellow as the weed in which they live. Between patches of weed one may sometimes see a Portuguese man-of-war, a boneless, spineless creature re-

lated to the jellyfishes. It is indeed a strange form of life. Here, too, may be seen a giant squid or an octopus. There are also little sea horses, tiny fish with tails like hooks, by means of which they hang to the sargassum. One of these strange creatures is pictured in Fig. 152, *b*. Can you see why they are called sea horses?

Definite life cycles are found in ocean life

One of the most curious recent discoveries in natural history has to do with the life history of our common eels, which you have doubtless seen in fresh-water ponds or near the shore in salt water. For years boys used to catching eels on their fishlines wondered why they never caught any apparently young eels. Scientists, on the other hand, were puzzled to find eels identically alike in both fresh water and salt water. For example, similar types of eels were found in bodies of salt water such as the ocean and in landlocked lakes and ponds as far as two hundred miles inland. How did they get there? The mystery was solved when scientists collecting specimens in the Sargasso Sea found eels breeding in the deep waters there, two thousand miles from land. The tiny young eels were so unlike their parents that they had not before been recognized as eels. It was further learned that by the time the young are about two years old they have somehow found their way to the mouths of fresh-water streams, some to the shores of Europe and others to the eastern shores of America. From there they swim up the rivers and live in fresh water until they are mature.

The life cycle of the eel is partly in fresh water and partly in salt water

The adult eel lives in its new environment for many years. Suddenly, one day, for some reason as yet unknown, it starts back over the journey taken years ago. Down small streams and rivers it goes on its way back to its birthplace far out in the broad sea. There eggs are laid, after which the adult eel dies. The eggs hatch, young eels develop, and the same life cycle is begun again.

These curious migrations of eels and of some other fish are necessary events in their life cycle. This cycle from salt water to fresh water and again to salt water includes several hundred miles of travel. As you follow the eels from the Sargasso Sea, some to the shores of America and others to Europe, and then back again to their breeding place, you must wonder how they find their way.

The differences in physical conditions in the open sea are between conditions on the surface and conditions at great depths. On the surface there is some difference in temperature; but the change from day to day is very little, and the change through the season is through a range of not more than a few degrees.

On the surface, organisms are exposed to sunlight. As depth increases, darkness increases. Light penetrates to a considerable depth, but below some five hundred or six hundred feet is a region of everlasting darkness.

The abundance of tiny organisms on the surface of the sea has already been mentioned. Many of these tiny organisms are green plants. They grow and manufacture food just as land plants do. The plants are most numerous in the spring, and along with their development come many forms of small animal life to feed upon the tiny plants. These tiny organisms, both plants and animals, are food for larger animals, and these in turn for still larger ones. Food for all the fish and other animals that live in the sea has its origin in these floating or swimming "gardens."

In the north Atlantic the herring is a most abundant fish. Herring travel in schools, or shoals. A single school may cover as many as four or five square miles and may contain as many as two or three billion fish. Mackerel are somewhat larger than herring. These too travel in schools in which the number of individuals runs well up into millions. In addition to these there are salmon, codfish, and others. The average annual catch of salmon alone exceeds a billion pounds. A haul of salmon is shown in Fig. 153.

U. S. Bureau of Fisheries

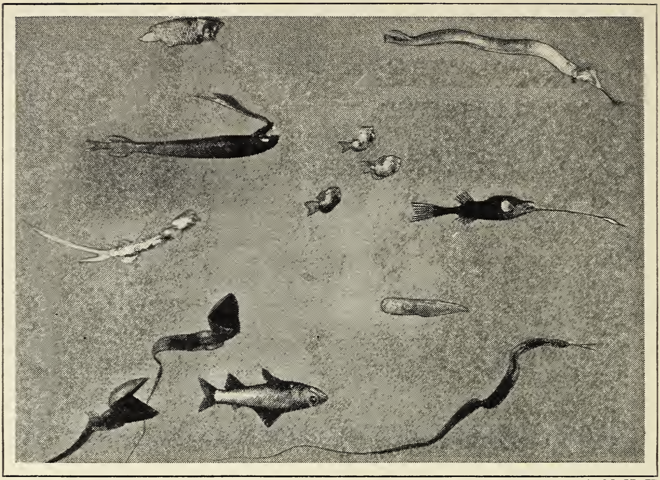
FIG. 153. Fishing is an Important Industry depending upon Ocean Life

This large haul of salmon, after canning, may have been part of your food

Food for ocean life at great depths must come from the surface

The food of these fish has its origin in the tiny green plants that feed on the surface. No green plants can live at a greater depth than a few hundred feet. Life beneath the surface, then, depends upon food that sinks to it from above. Organisms living beneath the surface catch food as it slowly sinks toward the bottom. In the depths the animal life is distributed in zones. Fish adapted to live at a thousand feet cannot live at ten thousand feet. Physical conditions and the character of the food at hand force them to stay within their zones.

If you could picture the food supply sinking from the surface, you would see a considerable amount in the form of dead animals, large and small, on their way toward the bottom. Living things are there to feed upon them as they fall toward the bottom. Animals below must feed upon what escapes from above.



A. M. N. H.

FIG. 154. Organisms living at Great Depths are often peculiarly adapted to their Environment

Wherever there is food, it seems as if animals are there to feed upon it. Animals such as those in Fig. 154 have been brought up by dredging from depths greater than twenty thousand feet, and certainly there is life at greater depths. A limiting factor of life is food. There can be no life where there is no food. At greater depths the supply grows less, so of course the number of inhabitants at great depths must be less than at the surface.

Deep-sea fish are adapted to live under conditions of pressure and intense darkness

The strange-looking inhabitants of the deep (Fig. 154) are adapted to live in a strange environment. Some generate light as the firefly does on a summer evening. Possibly this light helps them to catch their food as it sinks through the darkness. It is the smallest particles of sinking food that are used first, and the food at great depths is likely to be in large pieces. The enormous mouths, sometimes larger than the remainder of the body, are

adapted for catching these large pieces. In these depths there is never a change from the intense darkness. The temperature, only a few degrees above freezing, remains the same, year in and year out. Certainly a monotonous place to live, yet there are organisms adapted to these peculiar physical conditions and quite unable to live under any other conditions.

On the sea as on the land there are differences in the physical conditions within the climate zones, and there are differences due to distance from shore and to depth beneath the surface. In all these areas there are living things, each adapted to live in its own particular environment.

The limiting factor of life is food to supply energy for the vital processes. In the extremes of cold of the interior of the antarctic continent there is not enough energy to support living things, and there may be in the extreme depths of the sea, far below the range of sunlight, regions in which no living things can live. Between these extremes and those which prevail in the equatorial rain forest is the range of physical conditions on earth. Throughout this range there are living things, varying in abundance according to the physical conditions that prevail. Throughout this range of physical conditions there are organisms of many kinds, each able to live in its environment because it is adapted to take and use from that environment the energy that is necessary for its vital processes.

Life in the sea is not subject to such extremes of physical conditions as is life on land. All this life, however, represents another form of adaptation and adjustment to the environment.

Can You Answer these Questions?

1. While both the arctic and antarctic environments are regions of extreme cold, there are several differences between them. Do you know what these differences are and what the reason is for them?

2. What differences are there between physical conditions on land and physical conditions in water?

3. What forms of land animal life are found in the Arctic? in the Antarctic? Why this difference?

4. How may the fact that plants and animals depend on each other be illustrated by life in the Arctic?

5. What examples can you give of the adaptation of life along the seacoast to the effect of the rising and falling tides?

6. Can you describe a sea anemone and its methods of securing food?

7. What is a coral reef? What is the source of the material of which it is composed?

8. What is the explanation for the Sargasso Sea?

9. What do you know about the life cycle of an eel?

10. Where do the deep-sea fish get their food?

11. Why is it that even in extreme heat or extreme cold the temperature of ocean water changes very little?

Questions for Discussion

1. How do you think the stories of sea serpents start? Do you think there is any truth in them? What form of life do you think these so-called sea serpents might be?

2. How do you think an eel gets over waterfalls from the ocean to fresh-water lakes?

3. Do you think that the stories of the Sargasso Sea as a graveyard of abandoned ships might have any foundation of truth?

4. For a long time most of the polar exploration was confined to the north polar regions. Can you think of any reasons why this was so?

5. What living things experience the least change in physical conditions throughout the year?

Here are Some Things You May Want to Do

1. Have you read anything written by William Beebe? He has spent a great deal of time in exploring the depths of ocean waters. See if your library has any of his books. The *National Geographic Magazine* has had articles written by him.

2. Another scientist who has spent much time in exploring tropical waters is Captain Williamson. Have you ever seen any of his pictures of under-sea life? See if you can find any of his writings.

3. There are many books on polar exploration. The latest, of course, are by Rear Admiral Byrd. Some men before him, however, made attempts to reach both poles. Their books will tell you a great deal about the polar environments. See if your library has the works of Rear Admiral Peary, who discovered the north pole. Amundsen, a Norwegian, was the first to reach the south pole. His story too is in book form. Then there was Captain Scott, an Englishman, who after terrific struggles also reached the south pole, only to find that Amundsen had been there a few months ahead of him.

4. If you live near the seashore, visit it some afternoon at low tide and see if you can find any of the forms of plant and animal life mentioned in this chapter.

5. Once upon a time the whaling industry was carried on in sailing vessels, and the whales were killed by hand harpooning. See if you can find out anything about the whaling industry today. Has it changed?

6. Do you know how important a part the fishing industry plays in supplying the food for the United States? See what figures you can find on the fishing industry, and prepare a class report about it.

Chapter XIV · How does Man protect himself from Discomfort and maintain his Health through the Changing Seasons?

Suppose some afternoon when you had a little time to spend you walked into your local library and picked up a book dealing with the animal life of the world. Suppose you opened the book and suddenly found a picture of a polar bear resting in the shade of a dense jungle. Suppose you looked farther and found a picture of an elephant marooned on an iceberg in the Arctic and, still farther, of a whale swimming along on the surface of a fresh-water lake. What should you think?

These things are ridiculous, you say? Of course they are. But why are they? If you will think about it a little, you will probably say that the animals mentioned do not belong in such environments. Animals of the north, you will say, are adapted to live in a region of cold, and animals of the torrid zone are adapted to live in a region of heat.

Recall the chapters you have read in this unit. They show life as it exists under different physical conditions. You have seen the polar bear at home in the Arctic, the camel at home in a desert environment, and a whale in the deep waters of the ocean. If you try to imagine these animals in other environments, you soon come to the conclusion that most living things are adapted to live in a rather narrow range of physical conditions. If they are to live successfully elsewhere, they must be protected by the efforts of man from the harmful effects of the new conditions of climate and other factors of the environment.

Most things are adapted to live in a narrow range of physical conditions

Notice that we say that *most* living things are adapted to life within a rather narrow range of physical conditions. There is one organism which can live in a wide range of

physical conditions. Can you guess what that organism is? Of course, it is man himself. Human beings live all the year round in all the zones except the south frigid zone. They move from the extremes of one region into the opposite extremes of another region and continue to live in health and relative comfort. It may be argued that man is best adapted to life in the temperate zones, for it is within these zones that we find the greatest nations of the world. There is some evidence to support this argument. Nevertheless man does live elsewhere, and changes his home when occasion demands it.

Man can adapt himself to life within a wide range of physical conditions

Here, then, you see man as superior to other organisms. Animals other than man are adapted to live in the environment as it is. They cannot change it, and there is no evidence that they can plan for protection against heat and cold. The environment is there, and they are either adapted to live in it or they die.

Man is superior to other animals

Let us consider some further evidences of man's leading position among living organisms. He is superior to other animals in his ability to remember the experiences of the past and to plan his future from what he learns through experience. It is through exercise of this ability that he has learned many things about his environment and has learned to protect himself against extremes of heat and cold. Man can live comfortably through conditions which, except for his use of intelligence, would cause his death. By careful planning, as shown in Fig. 155, *a*, he may live in relative comfort through the extremes of cold and darkness of an antarctic winter. He may build for himself healthful and comfortable living quarters, similar to those in Fig. 155, *b*, in the regions of heavy rainfall in the torrid zone. He can go up higher in the air than any bird has ever flown, and he can go down to great depths in the ocean. Man is the most intelligent and the ablest of all animals. He plans his

Man uses past experiences in planning for the future

environment, and in so doing seeks to establish conditions favorable to health and comfort.

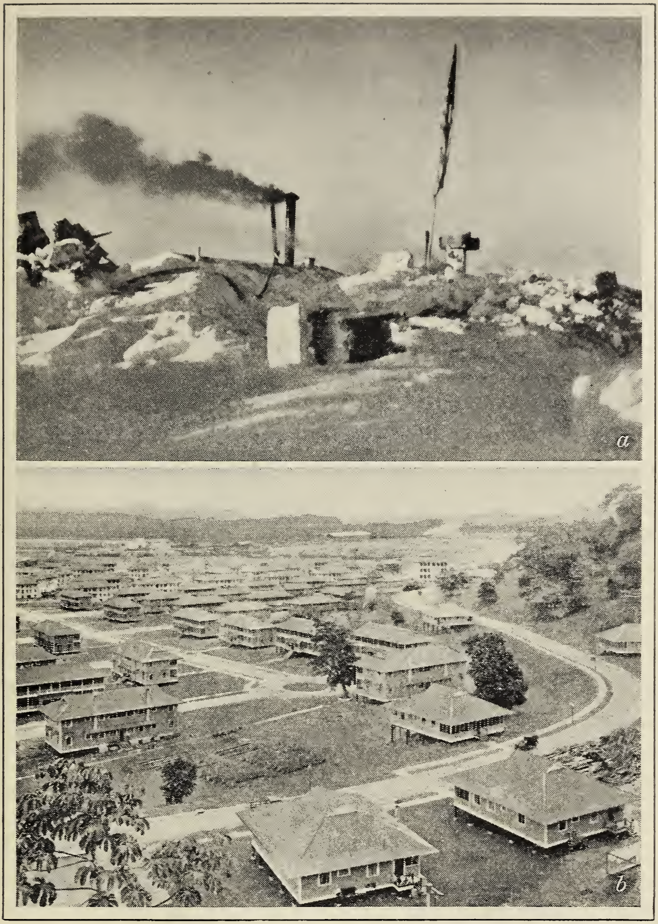
It is obvious that man is able to control many features of his environment. As you look about you and see life today and contrast it with that of years ago, you soon realize that this control has extended in many directions. In science, industry, art, literature,— in fact, in almost all the divisions of our life,— one can see the exercise of this control.

Man exercises control over his environment

Of all the controls that man has sought to achieve, however, one of his greatest problems has been to control his health. Through the exercise of intelligence man has learned to control many of the causes of ill health and many of the causes of discomfort. These controls have come as a result of better understanding of the environment. As a result of this understanding he is able to live in health and comfort through the extremes of the changing seasons and in the extremes of heat and cold of the different climatic zones. Much of the illness suffered by people results from failure to use the knowledge that has been learned through scientific study of the causes of illness. Through your study of science you may learn to protect yourself against illness.

A. How does Man protect himself against the Changes that come with the Changing Seasons?

Among the changes that come with the seasons in the westerly-wind belt are changes in temperature, in the amount of sunshine, and in the character of the food supply. With the changing seasons come changes in the character of many occupations. There are changes, too, in the character of recreational activities. Each of these is related to the health of man, and he must use his intelligence in order to maintain health and comfortable living as these things change.



a, © New York Times Co. and *St. Louis Post Dispatch*; *b*, The Panama Canal

Fig. 155. Careful Planning is Necessary for Human Life in Any Environment

a, Admiral Byrd's winter headquarters in Antarctica, 1929–1930; *b*, sanitary houses in the Canal Zone

Consider, first, protection against change in temperature. The temperature of a healthy human body is about 98.6° F.

Man must protect himself against seasonal change

You probably know something of the manner in which the temperature of the body is maintained. Food combines chemically with oxygen in the cells of the body, and this chemical change produces heat. When we exercise, more food is required and more heat is produced.

Exercise causes perspiration. High temperature in the surrounding air also causes increase in the amount of perspiration. Evaporation of perspiration carries heat away from the body. It is only under extreme conditions, therefore, that the temperature of the body rises noticeably above 98.6° F. except in the case of illness.

Under normal conditions the body loses heat most rapidly when the surrounding air is cold. In order that the temperature may remain the same while heat is rapidly lost, food must be used more rapidly. More food is required when the body is exposed to cold air than when it is exposed to warm air.

The human body has remarkable powers of adjustment. In extreme changes, however, we use our intelligence and wear clothing that assists in making these adjustments. When winter comes, we put on heavier clothing of fur and wool. When summer comes, we wear lighter clothing of cotton, silk, and linen. Look at the different types of clothing in Fig. 156. Are they suited to the environment?

Wool is the best protection in cold weather because it is the poorest conductor of heat. Linen is most satisfactory for hot weather because it is the best conductor of heat. In winter we wear wool for protection against loss of heat. In summer we wear linens in order that there may be loss of heat.

House-heating and artificial cooling are other methods used to protect the body against extremes of cold and heat. You may learn at a later time about the engineering prob-

Donald B. MacMillan

Fig. 156. The Clothing Suited for Life in an Arctic Environment is Unsuited to Life in the Tropics

lems associated with heating and artificial cooling. It is an interesting evidence of man's intelligence that he can put in a cooling plant that will maintain indoors an even, comfortable temperature when the temperature outdoors is 100° F.

We protect ourselves from discomfort through the changing seasons by keeping conditions around us so that we are not exposed to extremes of heat and cold. We seem to be healthy and comfortable when the air around us is about thirty or forty degrees colder than the temperature of our bodies. This is a temperature between 60° and 70° F. As the seasons change, we try to maintain conditions so that the temperature of the air around us is within this range.

Amount of sunshine is another changing feature of the environment. You have already learned that the farther one lives from the equator the greater the change in amount

of sunshine from summer to winter. Some exposure to sunshine is necessary for healthful living. This is especially true of young folks. For two reasons children frequently suffer from lack of sunshine in winter. In the first place, there are fewer hours of sunshine in winter. In the second place, it is more comfortable indoors in cold weather, and we stay in where it is warm. We need protection from cold, but for vigorous health we also need exposure to sunshine and exercise in the open air.

Man must adapt himself to changes in amount of sunshine

The character of the food supply changes as the seasons pass. Our food supply comes from living things. It comes indirectly from the chemical changes that go on in green plants. During the summer months green vegetables are abundant, but when winter comes they are not so plentiful. Green vegetables are important for healthful living, and through the exercise of intelligence man has learned how to obtain green vegetables throughout the year.

Man must plan his food supply

From all of this it may be seen that man's way of adapting himself to live through the changing seasons differs greatly from that of other animals.

B. What are the Diseases of Wintertime?

The extent to which man is able to protect himself from disease is one important measure of the extent to which he uses his intelligence. Many of the common illnesses are the result of unintelligent action. Illnesses are in part seasonal.

Colds in the head probably cause more discomfort to the human race than all other illnesses combined. Often, if neglected, a cold may have serious consequences. It is most common during late winter and early spring. Why is this? The answer to the question must be sought in study of the conditions which cause it.

A common cold is a winter disease

People are not equally susceptible to colds. Some have them frequently, others rarely or almost not at all. All of us have more or less natural resistance to colds; that is, we do not catch cold easily. The most effective means of fighting colds seems to be to build up resistance. It is necessary to prevent the breaking down of natural resistance.

You will recall that the temperature of a healthy person is 98.6° F. A rapid loss of heat from the body disturbs its normal functioning and seems to reduce resistance to a cold. The chill which you feel from wet clothing is evidence of rapid loss of heat. Exposure with wet feet certainly reduces resistance, and we speak of wet feet or wet clothing as a common cause of a cold. If we use our intelligence, we shall try to avoid this kind of exposure. If you get wet, change to dry clothing as soon as you can.

Careless exposure to cold and wet weather is responsible for many colds

It is interesting to observe that the dangers from wet clothing are less while you are exercising than while you are sitting still. More heat is produced by your body while you are exercising than while you are still. The rapid production of heat protects against the effects from rapid loss of heat.

You should not decide that mere exposure to cold weather is unhealthful. There is good reason to believe that exercise in cold air is healthful if you are properly dressed and if your clothing is dry.

In some sections of this country it is difficult to keep yourself, especially your feet, dry during the months of late winter and early spring. When snows are melting, there is always more or less slush underfoot. You can, though, protect yourself by changing to dry clothing when you come inside.

Lack of exposure to sunshine seems to be another thing that lowers resistance to a cold. Many people spend most of their time indoors during the winter. There is some evidence to show that too much indoor life with too little

Fig. 157. What are Some of the Habits which promote Good Health?

exposure to sunshine makes people more susceptible to colds in winter and spring than during other seasons of the year.

The common cold is a serious cause of illness among school children

As a cause of illness among school children the common cold leads all other diseases. Fig. 158 is a graph made of the figures secured through a study of school children over a three-year period in an Eastern city. Notice that for every thousand children there were over seven hundred cases of colds every year. How does this compare with some of the other causes of illness?

The true cause of this most common of all ailments is unknown, but it seems safe to say that the best way to

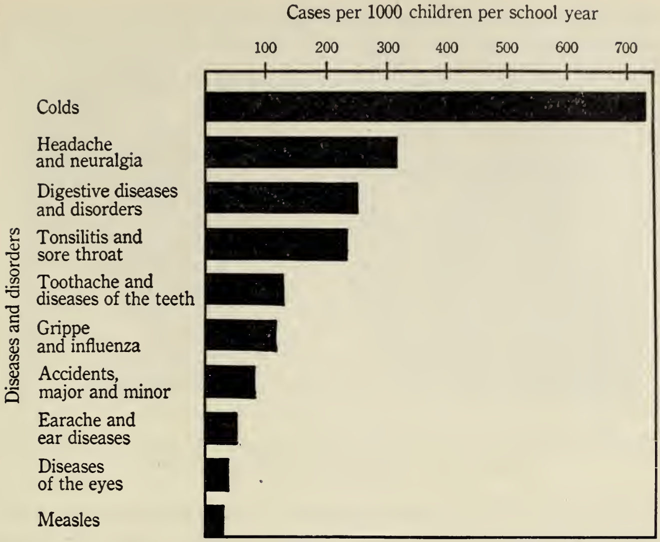


Fig. 158. Colds are a Serious Cause of Illness among School Children

build up resistance to the common cold is through habits of living that produce a healthy body. To build up a healthy body we must avoid exposure, eat wholesome food, play in the sunshine, and get plenty of sleep and rest. Fig. 157 suggests some ways to avoid catching cold.

Another protection against colds is to avoid the company of anyone who has a cold. Colds are certainly contagious; and although your natural resistance may protect you after an exposure, it is much safer to avoid the exposure.

Colds are often spread by carelessness

Coughing, sneezing, and spitting without protecting other people are vicious habits. Not only do they violate good taste and manners, but they also lead to the spread of disease among other people. Many who would look with horror upon a smallpox victim if he tried to walk down the street with them, think nothing of exposing countless people to

Fig. 159. People who are Careless in Coughing and Sneezing are not only Dangerous to Others but Unpopular as Well

the dangers of infection through coughing, sneezing, spitting, and other careless and unclean habits. Which of the people in Fig. 159 are you like?

Colds seem to be an indoor ailment. With the coming of the warm days of spring the season of colds passes.

Colds in themselves are not dangerous; but while a person is suffering from cold, other diseases may develop which are dangerous. There is very good evidence that resistance to other diseases is lowered by the effects of a cold. Among the serious disorders that may develop as after-effects are sinus trouble, influenza, bronchitis, pneumonia, and tuberculosis. The person who says he will "wear off a cold" by continuing at his work while he is running "only a slight fever" is not using intelligence in the care of his health.

Colds may have serious after-effects

The "catching" diseases are generally more prevalent in winter than in summer, probably because we live indoors more in winter and associate more closely with other people. You cannot catch another person's illness unless you allow the germs of his disease to get into your body. This may

happen if you get too close to the diseased person and especially if you and the diseased person are careless. Diphtheria, scarlet fever, smallpox, chicken pox, and whooping cough are contagious diseases most common in winter.

Diphtheria is one of the diseases the cause of which is well known. It is caused by bacteria (plants so small they can be seen only through a microscope) that for some reason seem adapted to grow in the human throat. The little organism is hurled from the throat when a person who has the disease sneezes or coughs. It cannot remain alive in the air for very long. If, however, you are close to the sick person, some of the living bacteria may be carried to your throat in the air you breathe. Bacteria may be transferred on pencils or other objects, especially those which the sick person may have had in his mouth.

Diphtheria is a disease caused by bacteria

This tiny organism produces others of its kind very rapidly. A single bacterium may by cell division become two bacteria. Each of these may divide and form two more. A single organism may be parent to a very great number in a short time. Bacteria, like other organisms, must use food and must discharge the waste products formed from using the food. The waste product from these bacteria is a deadly poison to man. It is for this reason that this disease is so dangerous.

The poison formed by these bacteria is called toxin. The treatment for the disease is a treatment that destroys or counteracts the effects of the poison. You probably know that the treatment for diphtheria is the use of antitoxin (*anti* means "against"). Antitoxin works against the effects of toxin. Before the discovery of antitoxin, diphtheria was one of the most dreaded diseases. Today it is not a dreaded disease in the same sense, for we know how to control it. If antitoxin is used promptly after the first symptoms appear, the illness is usually not serious.

Diphtheria may be prevented by the proper treatment

Department of Health, New York City

Fig. 160. The Toxin-Antitoxin Treatment develops Immunity to Diphtheria

Have you had this treatment?

A person who has had this disease usually acquires an immunity to it; that is, he does not have diphtheria a second time. A method is now known and used widely for developing immunity by artificial means. This so-called toxin-antitoxin treatment is easily taken. Children who have taken the treatment, as in Fig. 160, will never have diphtheria.

The prevention and cure of diphtheria are among the great achievements of medical science. Some forty years ago it was a very common disease. It was learned in 1883 that the disease was caused by bacteria. In 1894 the antitoxin treatment was introduced. The use of toxin-antitoxin to develop immunity was introduced about 1916. These achievements have made it possible to bring diphtheria almost completely under control.

Smallpox is another illness, once terribly dreaded, that has been brought under control.

It is estimated that in the eighteenth century over sixty million people died in Europe as the result of smallpox. Even in the United States epidemics were not infrequent. Smallpox is a highly contagious disease. Unless guarded against, it spreads rapidly. Today, as the result of scientific study and measures of prevention, it is rare indeed in any section of the United States. Yet its control is fairly recent. Just before the year 1800 an Englishman named Edward Jenner found evidence that if a person were vaccinated it protected him against smallpox.

Smallpox at one time took a heavy toll of life

Today vaccination is required in many parts of this country as well as in many other parts of the world. All the figures that we have point to its value in the prevention of smallpox. Let us look at some of these figures. In Prussia between the years 1868 and 1874 the annual death rate from smallpox was about 85 per 100,000 inhabitants. Since 1874 vaccination has been required in Prussia. In the years 1875 to 1886 the annual rate dropped to less than 10 per 100,000 inhabitants. Figures collected in the United States tell a similar story. Contrast two states, one with and the other without a law requiring vaccination. Over an eleven-year period, from 1913 to 1923, the first state had less than 500 cases; the latter, over 50,000, in spite of the fact that the population of the former state was 50 per cent greater than that of the latter.

Vaccination prevents smallpox

Scarlet fever is a third dreaded disease of winter. Medical workers have not been so successful in developing either a cure for scarlet fever or a means of preventing it. It is very contagious, but the organism that causes the disease has not been discovered. There has been during the past several years a marked falling off in the number of cases. This is without doubt due to strict enforcement of quarantine.

C. What are the Diseases of Summertime?

A much dreaded disease once common in summertime is typhoid fever. It is caused by bacteria that may live within the organs of digestion. Like all other bacteria, they use food and give off waste products. Waste products from most bacteria have no harmful effects on us, but wastes from these, like the wastes from the bacteria causing diphtheria, are poisonous. Each kind of bacteria produces a different effect upon the body. The poisons are absorbed in the blood and distributed throughout the body. The symptoms of disease are the effects produced by these poisons.

Typhoid fever is a filth disease and can be controlled by proper sanitary measures

Typhoid bacteria enter the body with our foods. In the intestine conditions are favorable for their growth. Typhoid, like other diseases, has been brought under control by methods of prevention. Typhoid fever is a filth disease. Since the organism lives in the intestine, it is obvious that we cannot "catch" typhoid unless some of the waste products from a person suffering with the disease get into our foods. It was learned from study of the causes of the disease that these bacteria are most likely to gain entrance to our bodies through water and milk. As sanitary measures were developed for protection of water and milk supplies, typhoid began to disappear. Some figures may prove interesting. For several years in a Mid-Western city the death rate from typhoid was over 120 per 100,000 inhabitants. In 1907 a new filtering plant was added to the water system. By 1910 the rate had dropped to slightly over 20, and today the disease is practically unknown there. Similar figures can be found for many other localities.

It was learned, too, that bacteria may be carried from filth to food by flies. After this discovery most cities put on campaigns to destroy house flies. These campaigns

have been fairly successful, and in sanitary communities house flies are not numerous.

There have been no serious outbreaks of typhoid fever in large American cities for many years. In large cities the water and milk supplies are carefully controlled. Our greatest danger from this disease comes during vacation trips, when we are away from these carefully controlled water and milk supplies.

We may protect ourselves against typhoid fever by vaccination. The process is somewhat different from vaccination against smallpox, although the results are similar. In vaccination against typhoid a large number of dead bacteria are injected, or forced, beneath the skin. The dead bacteria produce an immunity similar to the immunity produced by having the disease. Immunity produced in this way will furnish protection for about three years.

Malaria is another seasonal disease in the temperate zone. It is caused by the bite of a mosquito that at some previous time has bitten a person suffering from malaria. It can be spread only during the season when there are mosquitoes. Control of this disease is accomplished through control of mosquitoes. These insects breed only in still water, and may be controlled by draining the swampy regions.

Most of the severe diseases that once caused suffering and death in the temperate zones are now under control. One feature in man's control of his environment through the changing seasons is his control of the conditions that might allow these contagious diseases to develop. If man does not continue to exercise control over the conditions that cause disease, these diseases will certainly break out again.

In every city there is a board of health charged with responsibility for keeping contagious diseases under control. The board of health must guard the milk and water supply, control quarantines, and inspect eating places and stores in which foods are sold.

D. How can you protect yourself against Illness?

Through the use of your intelligence you may protect yourself against illness. There is no simple rule to follow. Above all, guard yourself during winter against catching cold. You may do this by eating wholesome food, by protecting yourself from exposure and especially from wet feet, by playing in the open air, by getting plenty of sleep and rest, and by keeping away from folks who are sneezing and coughing. You may think that a cold does not amount to much, but the greatest danger from colds is that their effects lower your resistance to attacks by other diseases. In cases where influenza and pneumonia develop they usually come following a cold. There is good reason to believe that we have less resistance to attacks of other diseases, including tuberculosis, while suffering from a cold.

Intelligent living helps in healthful living

What about drugs and medicines? There is one fairly safe rule to follow, and that is to let them alone except when they are prescribed by a physician. Many people are unintelligent in the use of drugs and medicines. It is very certain that most of the medicines taken by people are not needed by them. The ailments they think they are treating are often imaginary, and the medicine is useless. When a person is really suffering from an ailment, his self-prescribed medicine is probably worthless and may be even dangerous. For these reasons it is safest to let medicines alone except as you are advised to use them by a capable physician.

Drugs and medicines should be taken only under a doctor's advice

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Man differs from other animals in that he is able to control, in part, the factors of his environment that cause discomfort and disease.

Can You Answer these Questions?

1. What is meant by the statement "Most living things are adapted to live within a narrow range of physical conditions"?

2. What evidence is there to support the statement that man is superior to other living organisms?

3. How is the temperature of the body maintained?

4. In what ways does perspiration help to maintain a proper bodily temperature?

5. How does food help to maintain the proper temperature of the body?

6. Is there relationship between sunlight and good health? What is the evidence?

7. What is a "common cold"?

8. What are some of the careless practices which may result in a cold?

9. Why is cod-liver oil sometimes an important aid in maintaining health, especially during the winter months?

10. What are some of the diseases which may follow as the result of a cold?

11. What is diphtheria? How may it be prevented?

12. What evidence can you give that vaccination prevents smallpox?

13. Why do we say that typhoid is a filth disease?

14. What is the proper place of drugs and medicines?

Questions for Discussion

1. How many examples can you give which will support the statement "Most living things are adapted to live within a narrow range of physical conditions"?

2. How many examples can you give to support the statement "Man can adapt himself to living within a wide range of physical conditions"?

3. Do you think it fair to say that animals do not plan their ways of living? How about the migration of birds? the hibernation of bears?

4. Do you think that vaccination alone is responsible for the great drop in the spread of smallpox? What other reasons may there be?

5. The statement is made, "Man is best adapted to live in the temperate zones, for it is there that we find the greatest nations of the world." Do you think this is so? What evidence have you?

6. Which do you think is the more healthful environment in which to live, the city or the country? What evidence have you?

7. You often hear of people who have a fever. What is a fever? What conditions in the body do you think are responsible for a fever?

Here are Some Things You May Want to Do

1. You can study the effect of proper food and diet for yourself through careful experiments with white mice or guinea pigs. Ask your science teacher to help you.

2. Throughout this book you have found the biographies of certain men outstanding in science. Should you like to write some of these biographies? Look up the stories of Jenner, Trudeau, Pasteur, and other men noted in the work of medicine, and write biographies of them. These may be presented in class.

3. See what figures you can find to show how medical science has succeeded in lowering death rates and illness rates. Check back over a period of fifty years for the United States or, if you wish, for your own community. Prepare graphs showing the figures you find, and present them in your class.

4. Prepare a list of rules for the prevention of common colds. If you think this ailment is not important, see if you can find figures which show the estimated cost of this common disease to people in the United States. Where should you look for such figures?

5. What do you know about fake medicines? Are all the medicines advertised in the newspapers safe to take? From time to time the American Medical Association has issued books on fakes and nostrums in medicine. Your library probably has these. See what you can find in them that you think might be of interest to your class.

6. Which disease has the highest death rate in your community? What one is the most common? Have you a public health department in your community? Ask it for this information, and see what it is doing to help in the fight against disease. Someone in the department would probably be glad to come to your school and talk to you about community health.

7. Keep a record of the number of absences from school on account of illness from colds. What can you do in your school to control the causes of colds?

8. Has there been a severe epidemic of contagious disease in your community during recent years? If so, in what season of the year did it occur? How many cases of illness were there? What was done by the Board of Health to bring the epidemic under control?

U. S. Geological Survey

Fig. 161. The Grand Canyon of the Colorado is Visible Evidence of the Effect of Some of the Forces that are changing the Surface of the Earth

UNIT IV

What has Man learned about the Forces that have helped to form the Earth?

Chapter XV · What Forces are wearing down the Surface of the Earth?

Chapter XVI · How is the Surface of the Earth Elevated?

Chapter XVII · Have the Changes on the Surface of the Earth caused Changes in Climate?

Chapter XVIII · What may we learn about the Plants and Animals that lived in the Past?

THE picture at the beginning of this unit illustrates a scene in the Grand Canyon of the Colorado. If you have ever visited this region, you know that no picture can do justice to it. No words can tell the feeling which comes as one gazes out across the rim for the first time. For miles and miles are rugged cliffs cut into terraces, castles, peaks, and turrets. The area is a mass of color—red, brown, gray, orange—resulting from layers of differently colored rock. In the bright sunshine these colors are vivid and sharp. As dusk approaches, they fade and combine into a mysterious curtain of blended color which falls softly to smooth the rough surface of peaks and gorges. If you have ever seen this change, you know it is easy to share the ancient belief of the Indians, who saw this region as the home and playground of their gods.

The Grand Canyon is not the only scenic wonder of this continent. How many others do you know? Niagara Falls? Yellowstone Park? Canadian Rockies? Zion National Park? Natural Bridges National Monument, in Utah? the Valley of Ten Thousand Smokes, in Alaska? Glacier National Park? Crater Lake? the Yosemite Valley? You can probably add others.

What have these to do with science? you may ask. Just this: Far better than any written description, each pictures on a large scale the effect of natural forces upon the environment. What natural forces? Driving wind and running water, moving glaciers, destructive chemical action,—all these and more. How much do you know about them? Have you any idea how they work? Can you recognize the results of such forces? Are they still at work? Have they ever been more powerful than they are now?

Keep these questions in mind as you read the next few chapters and, when you finish, see whether or not you have a more satisfactory understanding of what the scientist means when he says that the surface of the earth is continuously changing.

Chapter XV · What Forces are wearing down the Surface of the Earth?

What do you know about North America? Can you draw a fairly accurate map of it? Can you give the names of important cities? Do you know the story of how your nation began, what important events came later in its history, and how it is governed today?

Now suppose that, instead of questions about industrial and political geography, history, and government, you were asked what you know about the geological history of your country. Can you give as satisfactory an answer to this as you did to the other questions? Perhaps you might even have to ask what is meant by geological history.

Imagine that you can look down upon the surface of North America from west to east and from north to south, as from a balloon in the stratosphere, and thus view the entire continent spread out below you. What should you see? Perhaps a relief map such as that in Fig. 162 will help you. Extending north and south, paralleling the Pacific Ocean, is a high range of mountains which you know as the Rockies. Some of the peaks in this range tower between ten and fifteen thousand feet above the level of the sea. Some of them are snow-covered the year round. Eastward these heights slope into plateaus, and finally into vast plains which make up the central part of the country. Draining these plains, with tributaries from the west and from the east, is the mighty Mississippi River system, some four thousand miles long, which finally pours into the Gulf of Mexico to the south. Along the boundary between the United States and Canada, beginning about the center of the continent and running eastward, extends a great chain of five lakes, covering an area of nearly a hundred thousand square miles. Bordering these lakes on the

FIG. 162. What are the Main Relief Features of North America as shown on this Map?

north and the south are rich agricultural plains. Paralleling most of the eastern seaboard is another range of mountains, the Appalachians. These are plainly not so high as the Rockies. Along the shores of the Gulf of Mexico and extending well northward along the Atlantic Ocean is another region of rich lowlands.

This is a familiar picture, isn't it? But do you know how these mountains, these plains and plateaus, and these lakes and rivers were formed? Do you know how old they are? Do you think that they have been there from the be-

ginning of time and that they will remain for all time to come? These seem to be difficult questions. As you consider them, you soon discover that you know very little about your country after all.

To the unthinking observer, the shore line of the Great Lakes, the height of the Rocky Mountains, the depth of the Mississippi River, and the rocky beauty of the Grand Canyon seem to remain the same from year to year. The geologist, however, will tell you that this is not so. Further, this student of the history of the earth will tell you that there was a time when there were no Great Lakes, no Rocky Mountains, no Mississippi River, and no Grand Canyon. He will say too that there will without doubt come a time when all these surface features will present an entirely different appearance from that which they have today.

Many natural features have changed over long periods of time

If you ask him to tell you more about this, he will say that forces on the surface of the earth wear down mountains, fill up lakes, and change the courses of rivers. Other forces from the interior of the earth raise more mountains and elevate regions of land that now may be beneath the sea. He may end by saying that during the time since the beginning of the earth the regions where you now live have been elevated, worn down, even sunk beneath the sea, and then elevated again. This cycle has been repeated many times.

Geology deals with the history of the earth

As you consider such ideas, one thing is plain. These changes must go on so slowly that ordinarily people are not conscious of them. How, then, does anyone know what they are, how they have come to be, and what they have done? The rocky surfaces and the fertile plains are evidences of these changes. Through study of changes now in progress the geologist has learned to interpret the changes of the past.

A. How does Running Water affect the Surface of the Earth?

As a result of previous work in science or even of ordinary observation, the idea that running water does change the surface of the earth should not be new to you. Refresh your memory, if you wish, by some common observations. Notice the water that flows down the slopes near your home or your school after a heavy rain. Dip up some of this water in a glass tumbler and observe it closely. Usually it is muddy. Your reason tells you that it is made so by many little particles of soil carried in the water. Here is very simple evidence of the destructive force of water. During a heavy rain millions of gallons of water may fall on one square mile of surface, to run off in streams and rivers. Some idea of the amount may be gained when it is calculated that one inch of rain on one square mile is equivalent to about seventeen million gallons of water. If you could dip up this tremendous quantity of water glass by glass, each glass would be muddy. The mud in every case would be composed of tiny particles of soil. By examination with a microscope you could see that the soil is composed in part of tiny pieces of rock.

Running water carries away soil

Follow some water as it flows down a slope. It runs in little gullies. The steeper the slope the faster the water flows. The faster it flows the more soil it can carry. Examine the soil at the foot of a hill and you may see where particles are deposited. Such familiar observations, then, furnish convincing evidence that enormous quantities of soil are carried from higher to lower places by the water that falls during the succession of rains that come during one year.

What is the effect of all this? A scene like the one shown in Fig. 163 is common in many sections of the United States. The deep gullies in the hillsides have been cut out

U. S. Forest Service

Fig. 163. The Force of Running Water is One Important Form of Erosion

How might the destroying of this land be stopped?

by running water; and the soil that was removed has been carried to lower levels.

In imagination follow the water as it flows along, far beyond the limits of your community. It has collected in little streams that flow from the familiar hillsides. These in turn have united to form a brook which flows through the meadow. This brook may enter a creek some few miles across country. This in turn may become a part of a great river system. All along this journey you may see places alongside the streams where soil carried from higher levels has been deposited.

Even the large rocks known as bowlders may be moved. Look at Fig. 164. As the water flows over a stone resting on sand or soft dirt, it carries this away from the lower side of the stone. After a time the stone will turn over into the hole cut out by the water. As the process is repeated, large bowlders may slowly move downstream. The stone may strike against other stones as it rolls.

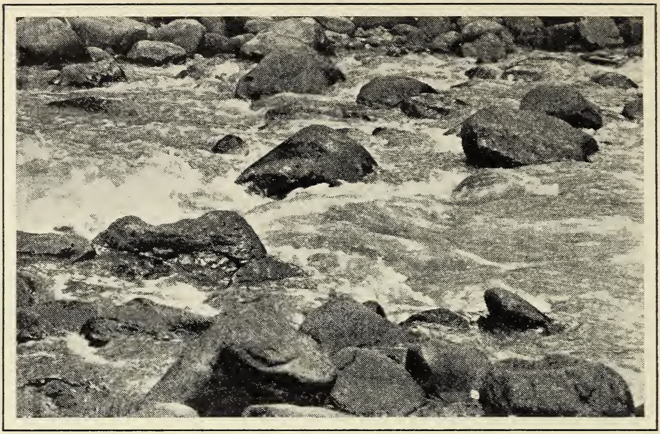


Fig. 164. The Force of Running Water is often Sufficient to move Large Bowlders

These bowlders will move slowly downstream

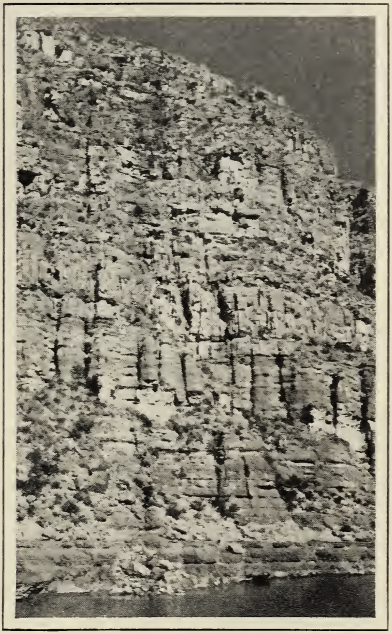
U. S. Geological Survey

Fig. 165. The Surface of the Rock over which Water flows may be worn Away

How were these potholes formed?

Small pieces may be chipped from it. This tends to wear off the sharp edges. Stones that have been carried for some distance by running water are often nearly round. Notice the rounded edges of the rocks in Fig. 164.

The surface of the rock over which the water flows may be worn away and the stream bed cut deeper by the grinding action of sand and rock carried by the water. There may be irregularities in the formation of the rock. It may be softer at one place than at another. Small pebbles may be caught in the rocky surface. The force of the flowing water drives the pebbles round and round. The friction of the moving pebbles against the rock grinds the hollows deeper and deeper, forming holes like those illustrated in Fig. 165. These are called potholes. As you can realize, many years were required for them to form.



U. S. Geological Survey

Fig. 166. Rocky Cliffs such as These are Evidence that the Force of Flowing Water may even wear away Solid Rock

As you travel along a river you may see hills on both sides. They are formed by the action of running water as it cuts its way from higher to lower elevations. The rocky cliffs along rivers, as illustrated in Fig. 166, are evidence that the force of flowing water may wear away rock.

Science Service

Fig. 167. This Airplane Photograph pictures a Part of the Mississippi River Delta

This delta has been formed by particles of broken-up rock carried down the river

The Mississippi River system drains thousands of square miles of land. Rain which falls over all this vast territory flows toward the mighty river. Each drop of it gathers mud as it travels along. During the course of time thousands of cubic miles of earth and rock have been carried away by it. The stream beds are slowly cut down to lower and lower levels. The material that is cut away is carried toward the Gulf of Mexico. In time of flood the current is swifter. Larger quantities of mud particles are carried. When the flood subsides, some of these particles are deposited along the shores. These will be picked up again and carried farther by the next flood.

In Fig. 167 is an airplane view of part of the Mississippi River delta. This delta has been formed from the particles of broken-up rock carried down the river. It has been esti-

mated that 1 cubic mile of earth is carried to the Gulf in about twenty years. In one year this is enough to form a layer of soil 1 foot thick over an area of 264 square miles. The whole area drained by this river system is about 1,250,000 square miles. The material carried to the Gulf is enough to lower the whole drainage area by 1 foot in about five thousand years.

The Mississippi River carries great quantities of silt

The amount of material carried in the water that may be dipped up in a drinking glass doesn't seem to be very much, does it? This little bit, however, when combined with all that flows down a great river, forms great deltas at the mouths of the rivers. The forces that wear away soil and rock and thus lower the level of the land are called the forces of erosion. For millions of years the rivers of the world have been eroding, or wearing away, the soil and rock of the valleys which they drain.

The forces of erosion have been operating for a long time

This work of erosion is observable in all parts of the world. The Danube River drains a large part of Europe. Its delta in the Black Sea is about a thousand square miles in area. Like other large rivers the Danube is filling the sea with sediment carried from long distances. In this case the sediment comes from the Alps and the Carpathian Mountains and from the valleys and plains along the way.

The Amazon River of South America carries the largest volume of water of all the rivers in the world. Its source, as you know, is in the high Andes Mountains on the western side of the continent. During the rainy seasons enormous volumes of water flow down the mountain sides to join the Amazon in its trip to the Atlantic Ocean. Along much of its course after leaving the mountains the river flows as a very slow stream. Therefore much of the material carried from the mountains is deposited as sediment on the bed and banks of the river before it reaches the ocean.

The Amazon carries silt from the western regions of South America to the Atlantic Ocean

Nevertheless great quantities of mud are carried to the Atlantic. This mud discolors the water of the Amazon to such an extent that it may be seen in the Atlantic as far out as a thousand miles from shore, where its dark appearance contrasts with the clear ocean. This river, then, like others, is tearing down the rocks of lofty mountains. It is spreading the rock particles over the lowlands of its valley and filling in the Atlantic Ocean.

One more outstanding example may be given. The Nile River drains a large portion of equatorial Africa and flows northward through the Sahara Desert to the Mediterranean Sea. During the rainy seasons the water flows in torrents as rapids, carrying a large amount of broken and ground-up rock from the highlands at the head of the river. As it reaches the lower part, however, the river flows over more nearly level ground. It slackens its speed. Rock particles from the mountains of central Africa and the rich soil from the rain forests and jungles are carried to lower levels and deposited as sediment. During the rainy season the river overflows its banks. When it recedes, a layer of rich sediment has been left. This flooded land makes one of the richest farming districts in the world. The lower Nile of the ancient Egyptians was the seat of one of the oldest civilizations that have existed on earth. The early Egyptians worshiped the Nile by impressive religious ceremonies. Evidently the people who lived in this region realized the importance of the force of running water as a factor in everyday life.

The fertile delta of the Nile was the seat of one of the earth's oldest civilizations

You may still be a little doubtful as to the real power of flowing water. "Oh, yes," you may say, "it's easy to understand how water can wear away soil. Soil is soft. But rock? That's another thing!" Perhaps it is, but water will slowly wear away rock too. The rocky edge of Niagara Falls today is more than seven miles farther upstream than it was some twenty thousand years ago.

In the introduction to this unit you read a little about the Grand Canyon of the Colorado. Should you like to know more about it? The region through which the Colorado River flows is unexcelled in the world for scenic beauty. The river itself flows as a raging stream in a canyon which is more than a mile deep at one part of its course. The work of this stream makes it possible to "read" from the walls of its canyon a long story of the changes that have taken place on earth.

The Grand Canyon is the result of gradual geologic change

From all the evidence it is plain that there was a time, probably sixty million years ago, when there was no Colorado River. Most of the region through which it flows was then covered by the sea. As time passed, powerful forces within the earth raised this region, forming the Rocky Mountains and the high plateaus. The change went on slowly, so slowly that if there had been people living there as it formed they would have been no more conscious of it than people today are of the changes now taking place. Through these millions of years of slow change the mountains were elevated until those regions once beneath the sea became regions of high mountains and plateaus more than two miles above sea level. As the land was formed, the rains fell upon it and the water flowed away, just as it does on the hillsides today.

Land areas slowly rise from the sea and slowly sink beneath it

Such was the beginning of the Colorado River. As the region was elevated more and more, the slope over which the river flowed became steeper and steeper. As a result the water flowed more rapidly and so with greater force against the rocks that lined its banks. Thus you see that during millions of years the river has cut its way down for more than a mile through the rock and has formed the deep canyon. In Fig. 168 is a cross section of the Colorado River. Can you find different layers of rock in this diagram?

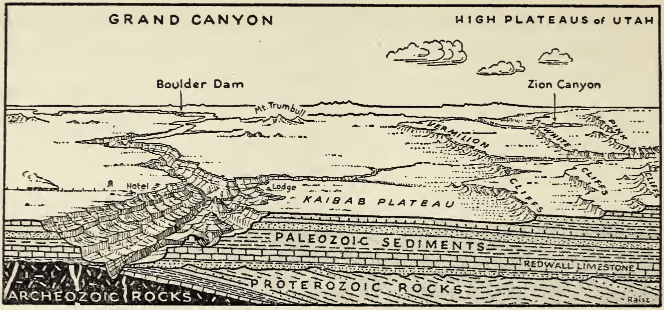


Fig. 168. The Colorado River today flows in a Canyon cut through Many Layers of Rock

These changes are still in progress. The river bed in its upper part is still high above sea level. The water rushes rapidly down the steep slope, carrying a large amount of broken-up rock. It carries away about a cubic mile of the mountains in thirty years. This is deposited as sediment in the Gulf of California and in the lowlands through which the river flows before it finally reaches the gulf. While the change is hardly noticeable from one year to another, yet it is obvious that if this process goes on long enough the Rocky Mountains will finally be worn away.

The earth is made up of many layers of rock

The Grand Canyon furnishes an observer with a cross section of a long period in the history of the world. By studying the walls of the canyon a geologist can tell how these rock layers were formed. Look at Fig. 161. He sees limestone deposits that must have been formed while the sea covered this area, for fossils of ocean plants and ocean animals have been found in the limestone. There are other rocks that must have been formed from soil deposited from streams that drained the land before the mountains were formed. It is obvious from a study of the canyon that the forces wearing away the surface of the earth today have been at work for a very long time.

All this is but one part of the story of the changes that running water can make on the surface of the earth. The geological history of the Mississippi River, of the Amazon, of the Nile, and of the Colorado is too long to tell here in full. The observations which one may make as he travels along the shore of any of the great rivers of the world furnish convincing evidence that water has been flowing on the surface of the earth for an extremely long time and, what is more, that during all this time it has been wearing down hills and mountains and carrying rock particles toward the sea.

The geological history of the earth covers a long period of time

B. How does the Solid Rock become broken up so that Running Water may carry it Away?

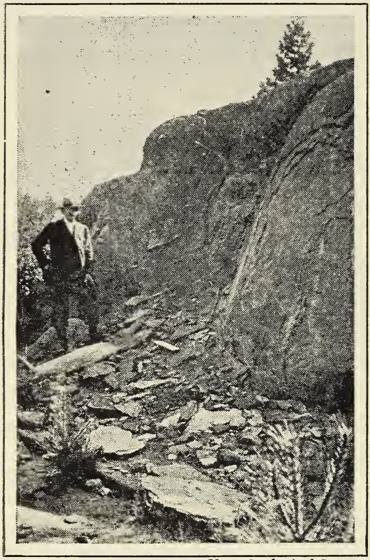
You already know that water expands when it freezes. You probably have seen the effect of this peculiar property, or quality, many times. On a cold winter's morning pieces of a broken milk bottle on the porch may have reminded you of it. More unfortunate, perhaps, have been experiences with frozen automobile radiators or with water pipes that have burst as the result of the pressure which water exerts as it freezes. This same property of freezing water plays an important part in the breaking up of rock. Water creeps into crevices on rocky hillsides. When cold weather comes, the water freezes, expands, and splits the rocks.

The force of freezing water breaks up rock

The part that temperature plays in the breaking up of rock is not confined to the effects of freezing water alone. If it were, many parts of the world would not be affected at all. Did you ever pour hot water into a glass vessel and hear, a moment later, the familiar sound of cracking glass? What has happened? Originally the glass was cool. When hot water was poured into it, the inside of the vessel ex-

panded rapidly. The outside did not, however, for glass is a poor conductor of heat. The unequal expansion caused a powerful strain. Glass is brittle and cannot stand such strain. Therefore it cracks under sudden changes in temperature. A vessel made of copper, silver, or aluminum does not break under similar conditions. These substances are better conductors of heat and, unlike glass and rock, are not brittle.

Changes in temperature cause rock to crack and chip away



U. S. Geological Survey

Fig. 169. Constant Heating and Cooling of Rocky Surfaces results in the Chipping Away of the Rock

Consider now the rocky slope of a mountain. The rock is composed of different minerals which expand and contract differently when heated and cooled. The hot rays of the sun play upon this surface during the hours of daylight, and the rock is heated. As night falls, it cools. What happens? Just like the glass, the rock breaks under the strain. The result is that over a period of years a mountain side slowly chips away. Water freezing in the crevices that are formed hastens the process. Sometimes the resulting rock particles are in the form of small flakes of rock; at other times large pieces break away. Look at Fig. 169. This shows the result of temperature changes upon a rocky surface. The pieces of rock at the foot of the cliff have been broken loose from the rocky surface.

C. Does the Material of which Rock and Soil are composed dissolve in Water?

Place a teaspoonful of clean table salt in a glass of water and stir it until the salt dissolves. You now have a solution which in appearance is just like pure water. Heat the solution until all the water has evaporated. What do you find? The salt is left as a solid. Table salt is a common substance, soluble in water.

There are substances in rock and soil that also dissolve in water. Evaporate a glass of clean spring water or some ordinary drinking water. Again you find a solid substance like salt left in the bottom of the glass. This solid substance dissolved in the water as it flowed along through soil and rock. The water of streams, like the water from the spring, has some substances dissolved in it. This soluble matter is carried by the flowing water to the ocean.

The water from a spring or stream does not taste salty, for it does not contain enough salt to be tasted. The salt slowly gathers in the ocean, however, and accordingly ocean water is so salty that it cannot be used for drinking. How does salt get there? Water leaves the ocean by the process of evaporation. The molecules of water may be carried by the wind over the land. By the process of condensation the water in the air may form clouds and fall as rain. The rain water collects in streams and flows back to the ocean. On the way there it gathers more soluble materials from the soil and rocks. When it evaporates from the ocean, the soluble material is left. As alternate evaporation and condensation continue, salt is slowly collected in the ocean. Every year there is a little more than there was the year before.

Many solids dissolve in water

Of all the substances in sea water, common salt, or sodium chloride, is found in greatest abundance. There are many other substances present. Altogether, compounds

of more than thirty elements have been found. Magnesium, calcium, and potassium, in combination with chlorine, bromine, sulfur, and some other elements, are present in considerable quantity. Compounds of copper, nickel, silver, and gold are present in extremely small amounts. All these substances taken together make up the salts of the ocean.

Sea water contains many substances in solution

Bromine, one of the elements found in sea water, has considerable commercial value. It is used to a great extent in photography and in medicine. There are no large deposits containing this element, and for this reason it is expensive. Just recently a floating chemical plant has been built, in which bromine is extracted from sea water. The amount of bromine in the water seems very small, only about one pound in two thousand gallons. The total amount in the ocean is, of course, extremely vast, for there are such large quantities of water. One cubic mile of sea water contains about three hundred thousand tons of this substance.

You may have heard of schemes for the recovery of gold from sea water. There are probably about eight million tons of gold dissolved in the oceans of the world. This seems like a great deal. It would be necessary, however, to extract all the gold from two hundred and eighty thousand tons of water in order to have enough to make one gold dollar. It is hardly likely that a process will ever be developed by means of which gold can be extracted profitably from ocean water.

There are in the world many lakes or inland seas which are very salty. Among these the best known are the Great Salt Lake, the Dead Sea, and the Caspian Sea. How are they formed? These lakes are located in regions where rainfall is slight and where water leaves the lakes by evaporation at least as rapidly as it is fed into the lakes by streams.

Some inland lakes are salty

At one time Great Salt Lake in Utah was part of a much larger lake, the area of which was equal to Lake Michigan

today. It is estimated that the water level was once more than one thousand feet above the present level. This immense body of water at first had no outlet, and the water level rose and fell only as climatic conditions changed. During a period in which the water collected faster than it evaporated, the level of the lake rose so high that it overflowed the rim of the mountains. This overflow cut a channel down through the mountains, and the water from the lake then ran as a river into the Pacific Ocean. These changes took place over a period of thousands of years. Gradually the climate of the region became warmer, and evaporation took place more rapidly. Finally the time came when more water evaporated from the lake than entered it, and over another long period of years the lake became smaller. The water level in the lake dropped below the level of the overflow channel, and again the lake had no outlet. Today the level of the lake is much lower than the gap formerly cut in the mountains, and it still has no outlet.

At the present time water is lost by evaporation at about the same rate as it enters from the mountain streams by which the lake is fed. Therefore the lake is not changing in size. As in the past, the rivers entering the lake carry some salt. When the water evaporates, the salt is left. The water of the lake, because of the salt, is denser than river or even ocean water. In fact, it is so dense that a swimmer cannot sink in it.

Caves are formed as underground water dissolves rock

Have you ever visited a limestone cave? If you have ever visited or seen pictures of one, you have probably asked the same question many visitors do, "How was this formed?" One of the most common forms of rock is limestone. Marble is a familiar form of limestone. Many regions have underlying layers of such rock, many feet in thickness. Limestone dissolves slowly in pure water; but if the water contains a small amount of acid, the stone is dissolved much more rapidly.

The most common acid in nature is carbonic acid. It is formed when carbon dioxide is dissolved in water. You probably know something about molecules and atoms and about chemical changes. The formation of carbonic acid from carbon dioxide and water and the action of carbonic acid on limestone are simple chemical changes. Carbon dioxide and water are, as you know, very familiar substances. When dissolved in water a molecule of carbon dioxide will combine with a molecule of water and form a molecule of carbonic acid. This change may be shown by a simple chemical equation, a kind of shorthand for indicating what happens:

$$\underset{\text{water}}{H_2O} + \underset{\text{carbon dioxide}}{CO_2} \longrightarrow \underset{\text{carbonic acid}}{H_2CO_3}$$

Carbonic acid is a very weak acid, but it will slowly dissolve limestone.

Here, then, are the conditions favorable for the formation of caves. Caves are formed only in a region of limestone where the flowing water contains carbonic acid. Let us follow the process. Water which fell as rain seeps downward from the surface of the earth through loose soil and porous rock. Where there are breaks in the limestone the underground water may flow into the break. In this case it flows along the cracks in the rock and dissolves the limestone, thus forming a cave.

The chemical action of carbonic acid on limestone may be described in chemical terms as follows: Limestone is calcium carbonate. The molecules of calcium carbonate contain one atom of calcium, one atom of carbon, and three atoms of oxygen. It can be written therefore as $CaCO_3$. This substance combines with carbonic acid and forms calcium bicarbonate, which is soluble. The molecular changes that take place may be shown in a simple chemical equation:

$$\underset{\text{calcium carbonate}}{CaCO_3} + \underset{\text{carbonic acid}}{H_2CO_3} \longrightarrow \underset{\text{calcium bicarbonate}}{Ca(HCO_3)_2}$$

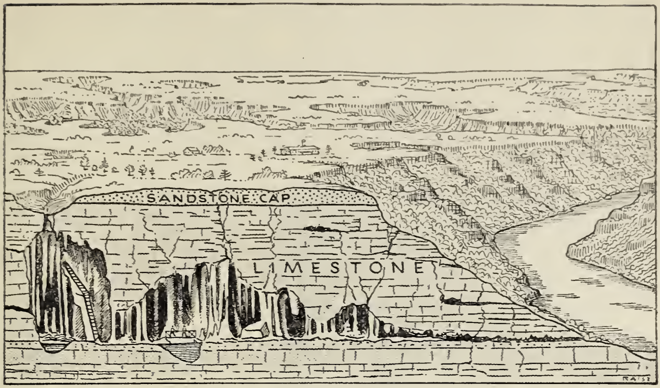


FIG. 170. Huge Caves are formed as Limestone is dissolved in Running Water

This is a cross section of Mammoth Cave, Kentucky

As a result of this chemical action the limestone is slowly carried away in solution. Let us look now at the effects of this chemical action in a typical cave, such as Mammoth Cave in Kentucky. Here the cave has been formed in a layer of limestone about three hundred feet thick. In places the cave is as much as three hundred feet wide, and the distance from floor to roof may be a hundred and twenty-five feet. The space within the cave was once solid rock. The diagram in Fig. 170 shows how an enormous cavern may be cut into rock by the action of flowing water carrying in solution a small amount of carbonic acid.

Stalagmites and stalactites are composed of calcium carbonate

In Fig. 171 you see one part of the interior of such a cave. Pillars called stalagmites seem to grow like giant mushrooms from the floor. Masses called stalactites hang from the ceiling like huge icicles. These are typical of such a cave. They are composed of calcium carbonate and are formed from calcium bicarbonate which was in solution in water. Water dripping from the roof of the

cave has seeped through limestone. It therefore carries calcium bicarbonate in solution. As the drop hangs from the roof, some of the water evaporates and some of the calcium bicarbonate changes to calcium carbonate. The comparison of these stalactites to huge icicles is a rather good one, for stalactites form from the roof of the cave in much the same way that icicles form from the eaves of a house. How about the stalagmites? Under ordinary conditions not all the water will evaporate where it seeps through from the roof of the cave. Drops will form and fall with a splash on the floor below. Further evaporation takes place on the floor, and calcium carbonate is deposited there, forming a stalagmite.

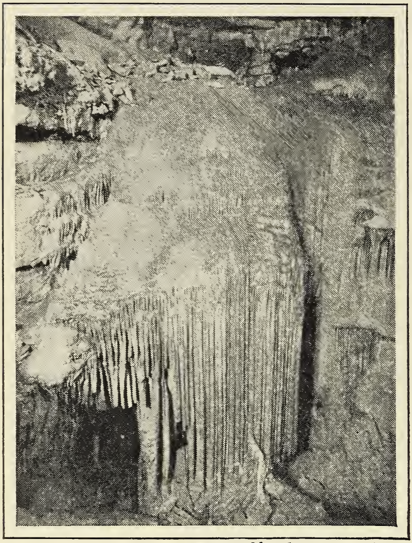


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Fig. 171. The Stalagmites and Stalactites in a Cave are formed by the Dissolving Action of Water upon Calcium Carbonate

This picture shows the Frozen Niagara formation in Mammoth Cave

The chemical change that takes place in the formation of stalactites and stalagmites is just the reverse of the one which takes place as the limestone dissolves. Evaporation of water in which calcium bicarbonate is dissolved causes calcium carbonate to form. The manner in which the molecule breaks up may be shown by an equation:

$$\underset{\text{calcium bicarbonate}}{Ca(HCO_3)_2} \longrightarrow \underset{\text{calcium carbonate}}{CaCO_3} + \underset{\text{water}}{H_2O} + \underset{\text{carbon dioxide}}{CO_2}$$

Of course the changes that go on while caves are forming are extremely slow. You would appreciate the length of time it took to form a cave if you tried to secure calcium carbonate by evaporating water collected from the roof of a cave. Huge quantities of water yield only a small amount of solid substance. But a small change continuing for an enormously long time has been responsible for the formation of Mammoth Cave.

The formation of a cave is a slow process

As you study the enormous caves found in Virginia, Kentucky, Arkansas, New Mexico, Colorado, New York, and other parts of the country and realize that all of them are the result of slow change, you gain a deeper understanding of the gradual work of natural forces. The stalactites and stalagmites themselves have taken long periods of time to form. The rate varies under different conditions, but you may think of the rate of stalactite growth as about one foot in length every six hundred years.

While these caves are places of great beauty, they also illustrate the powerful action of common substances. Here you see that water with carbonic acid in it dissolves and carries away many thousands of cubic feet of limestone. In the formation of stalactites and stalagmites you see that running water deposits limestone and fills up the caverns that have been millions of years in forming. The limestone that has been carried away by the water will be deposited elsewhere, and new beds of limestone will be formed. Thus the process is a continuous one.

D. Does the Force of the Wind change the Surface of the Earth?

Have you ever been caught in a severe windstorm? Whether you have or not, you have seen pictures of trees and buildings destroyed by the wind. Perhaps you have seen a strong gale raising clouds of dust from a dry road or

Fig. 172. Large Masses of Sand and Soil are sometimes moved by the Force of the Wind

This picture shows how sand from a wind-swept ocean beach may be moved farther and farther inland, covering the vegetation in its path

field. If you have been to the seashore or have seen pictures of a desert, you recognize sand dunes similar to those in Fig. 172 as masses of sand piled up by the force of the wind.

This force of rapidly moving air may be illustrated by an observation quite familiar to city dwellers. A stone or brick building becomes dirty from the soot and dust in the city air. It needs cleaning badly. How is this done? If you have watched such an operation, you know that it is one of sand-blasting. Air is compressed by an air pump and allowed to escape through the nozzle of a hose. Sand is carried in the rapidly moving air and is blown against the face of the building. The force of the sand blast quickly cuts off the dirty surface of the stone.

When sand is blown by the wind against a rocky surface, it cuts the rock in the same way as a sand blast does.

In time rocks exposed to wind-blown sand are worn away. In the desert the wind is the chief agent of erosion. Fig. 173 illustrates the effect of wind-blown sand upon rocky surfaces. One thing may be noticed in connection with this type of erosion. More sand is carried along near the surface of the earth than is carried higher up. For this reason projecting rocks are worn away fastest near the ground and tend to take the shape of huge mushrooms.

Wind-blown sand erodes rock

A. M. N. H.

Fig. 173. Rocks Exposed to Wind-Blown Sand are slowly worn Away

These curious rock formations in Monument Park, Colorado, show the effects of such erosion

The changes produced by wind are ordinarily not so noticeable as those caused by water, but the slow process continuing for millions of years produces great effects.

A strong wind over the desert may carry an enormous amount of sand. It has been estimated that a single storm in the Sahara Desert carried five hundred thousand tons of sand into the air. Some of it was carried across the Mediterranean Sea into Europe. Dry regions of the United States and Asia are located in the westerly-wind belt. In these regions the wind-blown dust is carried from the west toward the east. As a result parts of Kansas and of Nebraska are covered to a depth of as much as twenty feet with earth carried and deposited by the wind. In China there are deposits, in some places several hundred feet thick, that have been carried by the westerly wind from the high, dry plains of central Asia.

Wind carries soil to new places

E. How have Glaciers changed the Surface of the Earth?

Glaciers, like other things in the natural environment, tell entirely different stories to persons trained in science and to those who are not. To the latter a glacier is a thing of scenic beauty. Perhaps it brings a feeling of wonder and respect for natural forces. Perhaps it brings only a momentary interest similar to that secured from any other exciting scene. Think, for example, of walking and sliding over huge masses of ice in July, while people in the cities at the foot of the mountain are sweltering in summer heat.

To the person who has some knowledge of geology, however, the glacier is all of this and far more. It is visible evidence, on a small scale perhaps, of natural forces which have played a tremendous part in the geological history of this country. Did you know, for example, that the fertile lands of the Mid-Western corn belt are partly the result of glacial action? Did you know that the Great Lakes were really formed by the action of a tremendous sheet of ice as it crept along, tearing and gouging huge holes on the surface of the earth and moving the material to other regions? Perhaps part of this story may interest you.

Glaciation is a process of erosion

There are now but few glaciers to be seen in North America. The best-known are in Glacier National Park in Montana, on Mount Rainier in Washington, and in Alaska. In Europe the best-known region of true glaciers is in the Alps of Switzerland. These are regions of relatively heavy snowfall in winter. Because of high elevation the summers are not warm enough to melt the snow and ice. There are many places in the Rocky Mountains too where snow banks last through the summer, but most of these snow banks are not true glaciers. The interior of Greenland is today covered with glacial ice just as the northern United States and Canada were covered during the Glacial Age.

FIG. 174. Glaciers are Rivers of Ice which move slowly down the Mountain Side

Study this picture in connection with Fig. 177, which shows a cross section through a typical glacier, and with Fig. 178, which pictures a deep ravine cut by a glacier ages ago

A glacier is a mass of moving ice

What are glaciers, such as the one illustrated in Fig. 174? Briefly, they are rivers of ice. How are they formed? The answer is suggested above. The climate is such that more snow falls in winter than melts in summer. Gradually this snow becomes deeper and deeper. The weight of the snow above changes that below it to ice. In time these snow banks become huge rivers of ice which creep slowly down the mountain side.

Such, then, are the glaciers that you see in some of the national parks. "But," you say, "what about the glaciers that covered a large part of North America some thousands of years ago? How were they formed? What happened to them? Why aren't they here today? How do we know that there were any such glaciers?"

These are reasonable questions, and they can be answered. In order to answer them, however, one must use his imagination and go back into the past for some hun-

dreds of thousands of years. Remember that these changes did not take place overnight nor in a few years. Remember, too, that no one generation of people was conscious of them unless as a result of careful study, any more than we are conscious of the slow changes that are taking place on the surface of the earth today.

The climates of the world have changed over a long period of time

The story begins at a time when the climate all over the world was somewhat different from what it is today. This may seem strange, but there really is evidence of extreme world-wide changes in climate. Fossils of plants and animals that could have lived only in a climate such as now exists in Florida and Louisiana have been found in the northern part of the United States. These same regions, however, were apparently once covered with ice. Thus scientists believe that over a long interval of time these regions have experienced extreme changes in climate.

As the climate became colder, glaciers gradually formed over the northern part of the continent. Evidence we now have indicates that at one time the ice extended as far south as Long Island and New York City in the east and as far south as southern Illinois in the central states. The map in Fig. 175 shows the area once covered with ice. Was the region in which you now live at one time under glacial ice? If so, is there any evidence of it in your locality? The ice sheets over the northern United States were probably a mile thick, and those over Canada probably thicker. The glaciers were not confined to North America, for at this same time similar beds of ice spread over northern Europe and Asia.

Where did all this ice come from? Vast quantities of water evaporated from the oceans, condensed, and fell again in the colder climates as snow. The extent of this evaporation may be judged from estimates made that the ocean level was probably from two hundred to three hundred feet lower at the time of greatest ice extension than it is today.

FIG. 175. A Large Part of the North American Continent was at One Time covered by Ice as shown by the Map

Is your home in the shaded section? If so, are there any evidences of glacial action in your locality?

Here, then, is part of a cycle. In the beginning the climate was warm, and glaciers were unknown. Gradually the climate became colder, and the glaciers formed. The completion of this cycle will explain what became of the glaciers. Can you complete it? Of course! The climate changed again, and the ice melted. Only the Greenland ice sheet remains today, and it is even now receding.

As the climates changed, glaciers formed

Go back now to the beginning of the cycle and follow it a little more carefully. Before the ice came, the outline of the continent of North America was much as it is today. There were some striking differences, however. The Gulf of Mexico extended much farther north. The Mississippi River flowed in about the same position as now, and it had cut a deep valley. Its stream bed was near sea level, and it flowed as a slowly moving stream. There were no Great Lakes, but there was a deep valley of an old stream that had at one time flowed out toward the Atlantic Ocean, draining the region in which the Great Lakes are now located.

Now let your imagination carry you over many thousands of years, during which time climatic changes are taking place and a great sheet of ice is forming. In time this immense glacier covered a region as far south as the Ohio River. Go a step further and, in imagination, see this ice sheet! First of all, notice that it is moving! Perhaps you did not know that ice flows. It does, however. Its motion is, of course, very slow. The most rapidly moving glaciers today move only a few feet in twenty-four hours. These ancient glaciers probably did not move more than a foot a day. At this rate they would move only a hundred miles in about fourteen hundred years. Perhaps they moved even more slowly. The main thing to remember is that glaciers thousands of years ago, just as today, did move, and that this motion, while slow, represented a powerful force.

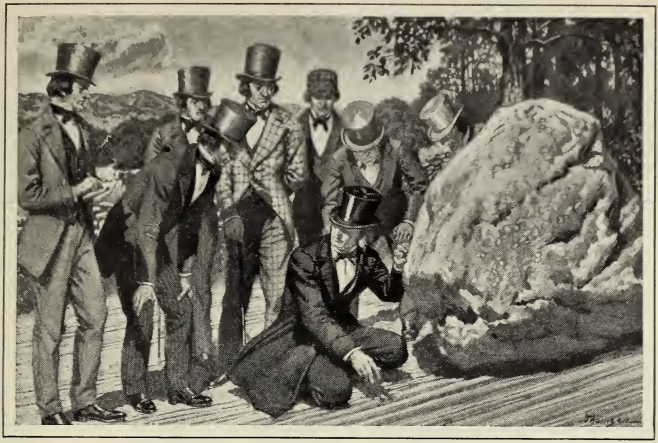

FIG. 176. LOUIS JOHN RUDOLPH AGASSIZ, *a Pioneer Student of the Work of Glaciers* (*1807–1873*)

AS A small boy in his native Switzerland, Louis Agassiz saw many glaciers, and he saw the scarred surfaces of the rounded bowlders left where the glaciers had melted. As a grown man in Massachusetts he saw the same kinds of rounded rocks and the same U-shaped hills and valleys. He drew the obvious conclusion—Massachusetts had once been covered by a glacier. No one had thought about this possibility before, but all our observations in the last half-century have tended to prove his conclusion. Agassiz was, for many years, a professor at Harvard University, and he trained many students who have become leaders in their turn, both in geology and in biology. He specialized in the study of fish and the biology of ocean life. He was the first prominent teacher in America whose students learned by trying things for themselves in a laboratory, rather than by listening to a teacher's lectures. A favorite saying of his, "Study nature, not books," showed how he thought we ought to learn about our environment. Do you agree with him? Agassiz himself believed several theories which afterwards proved to be false. But because he had trained his students well in the use of the scientific method, so that they were not afraid to question authority, these same students were among the first to discard the old and accept the new theories. The poet Longfellow wrote a poem called "The Fiftieth Birthday of Agassiz," which he read at a party. This you may find, if you wish, among Longfellow's poems in your library.

As you see this glacier, notice that loose bowlders are picked up from the rocky surface over which it moves and are held frozen in the ice. As the glacier moves, the bowlders are pushed along over the ground. The pressure, as you can imagine, is enormous. Ice a mile thick exerts a pressure of more than three hundred thousand pounds on each square foot. Imagine a bowlder slowly moved along over a rocky surface with such a pressure upon it. It is easy to see that the bowlder and the surface over which it moves along would both be slowly ground into tiny bits. Great grooves might even be gouged in the rocky surface. The ice, as it moves, fills the low places and wears down the sides of hollows. The farther it moves, the more bowlders, pebbles, and soil it gathers. See Fig. 177.

As the glacier moves along, the rock beneath is ground into fine particles

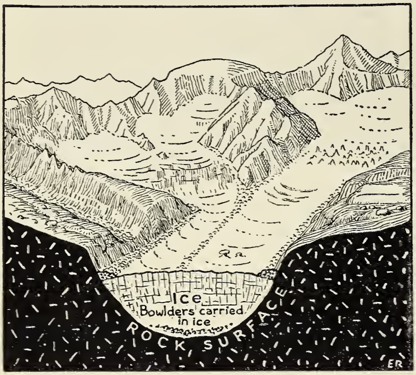

FIG. 177. The Tremendous Pressure of a Moving Glacier is Sufficient to wear away the Solid Rock Beneath

The process is hastened by the bowlders held fast in the ice

After a time the glacier is carrying with it an enormous quantity of rock which it has gathered as it moved along. What happens to this? You must recognize that some of the ice will melt. In summer there will be rapid streams flowing from the glacier. Some of the powdered rock will be carried off as sand and mud in this water.

Let us repeat the statement that all these changes took a tremendous amount of time. A record of the climate kept for a hundred years would have shown but little change. The average temperature during a thousand years may

FIG. 178. The Moving Glaciers often cut out Deep Valleys and Ravines

Tuckerman's Ravine, in the White Mountains of New Hampshire, was formed by such a glacier. Study this picture in connection with Figs. 174 and 177

not have changed more than one degree. The average temperature several thousand years ago, when the glaciers covered the northern United States, was probably not more than ten degrees colder than the average temperature of the same region today.

Climatic changes take place slowly

Now, in imagination, jump ahead a few thousand years to the time when the climate began to get warmer. More snow now melts in summer than falls in winter, and the edge of the ice sheet begins to recede. How long did this process take? On one region where careful study has been made, it was found that the edge of the ice sheet receded a hundred and eighty-five miles in forty-three hundred years. It is estimated from this and many other observations that some thirty thousand years have passed since the ice began to recede.

What were conditions on the surface after the glaciers had disappeared? The rock which had been carried by the ice was left when the ice melted. Some of the finest particles were carried away in the streams that carried the

water from the melting ice. The remainder was left where the ice melted and may be seen as evidence of the movement of the glaciers, as well as of the effect they had upon the surface of the earth. Glacial deposits of soil, sand, pebbles, and large bowlders are distributed over the landscape of regions once covered by glaciers. In some places these deposits are several hundred feet thick. The bowlders may weigh several tons. Some of them were surely carried great distances. Granite bowlders have been found in southern Ohio. The nearest deposits of granite rock similar to these bowlders are several hundred miles to the north.

Many evidences show the work of glaciers

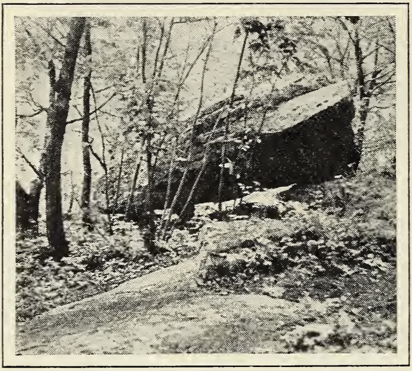

Fig. 179. Great Bowlders, similar to this One, were left when the Edge of the Ice Sheet Receded

The moving ice dug out the deep valleys of the rivers which existed before the days of the glaciers, and tended to make them deeper. The glacial remains, commonly called drift, tended to fill them up. Many other changes were made. The Great Lakes were formed in an old river valley. Rich agricultural soil was deposited in some regions, and bowlder fields were formed in other places.

If you live or travel in this region formerly covered by glaciers, you may see abundant evidence of glacial action. If there is a rock surface, you may find glacial scratches on it. These were formed by the bowlders and pebbles held in the ice as the ice moved along. You may see great ravines such as the one in Fig. 178. You may see large

bowlders like the one in Fig. 179. These may have been carried many miles by a glacier and have been left when the ice melted. You may see great deposits of sand and gravel. There may be old stream beds now dry that once carried the water from the melting ice. The rich farm land of the corn belt is of glacial origin. From all this evidence you can be sure that the surface of the earth was enormously changed by the coming of the glaciers and by the action of the running water that formed as the ice melted.

From this study of wind and streams, the action of water in dissolving rock, freezing and thawing, and glaciers you see that forces from these agencies are slowly wearing down the surface of the earth. The changes go on slowly, but during the millions of years of the earth's history high mountains and plains have been worn down, and the materials of which they were composed have been carried to the sea. Forces of erosion are slowly but continuously wearing down the surface of the earth. As you continue your study you will learn how other forces cause the earth's surface to rise again.

There are many natural forces which tend to change the surface of the earth. Among these are changes in temperature, the action of water, the action of wind, and glaciation. These are called the forces of erosion, for they are lowering the surface of the land. All evidence at hand indicates that they have been at work for long periods of time.

Can You Answer these Questions?

1. What is meant by the geological history of a region?

2. State some of the evidences that the surface features of the North American continent have changed and are changing.

3. How can you demonstrate that running water carries soil?

4. What is the explanation of potholes?

5. The deltas of large river systems are often regions of rich agricultural land. Why should this be so?

6. Why do you suppose the ancient Egyptians worshiped the Nile?

7. Can you explain how the Grand Canyon was formed?

8. What evidence is there that the region of the Grand Canyon was at one time under the sea?

9. How does the effect of freezing water help to produce soil?

10. Are any of the salts of the ocean of commercial value?

11. What is the origin of a salt deposit?

12. What is the origin of limestone caves?

13. How are stalagmites and stalactites formed?

14. To what extent is wind erosion responsible for changing the surface of the earth?

15. How are glaciers formed?

16. Can you tell the story of the great ice age of America?

17. How did the glaciers help to prepare the rich soil of some agricultural areas of the United States?

18. Why does the Amazon River not have a delta similar to that of the Mississippi?

19. How is carbonic acid formed?

Questions for Discussion

1. Suppose you owned farm land on a hillside where the forces of running water carried away great amounts of soil every time it rained. Could you do anything to protect your land?

2. Why is the water of the ocean salty, while the waters of many lakes and streams are not?

3. If you look at pictures of the Rocky Mountains in the West and of the Appalachian Mountains in the East, you will see that the peaks of the former are sharp and rugged, while those of the latter are smooth. Does this tell you anything about the age of these mountains?

4. The government is using reforestation as a means of preventing soil erosion. Can you explain why this should help?

5. Is soil that is constantly subjected to the effect of running water as good for agriculture as soil that is not? Can you think of any reasons why it should not be? Water is necessary for plant life, is it not?

6. What do you think plant and animal life was like during the great ice age?

7. Which of all the forces mentioned in this chapter do you think has had most to do with changing the surface of the earth?

8. Why are the different layers of rock in the Grand Canyon of different colors?

Here are Some Things You May Want to Do

1. How well do you know your own locality? Are there any evidences of erosion there? Did the glaciers ever cover the part of the country in which you live? Are there any evidences of this? Are there mountains near by? What do you know about their history? A well-planned field trip should give you from your own community many illustrations of the forces discussed in this chapter. Organize such a trip and see what you can find.

2. Many of the regions set aside by the government as national parks show evidences of forces that are wearing down the surface of the earth. How many of these regions are you familiar with? The introduction to this unit mentions some of them. See if you can find out anything about them and the forces that produced them.

3. Do you like to write stories? Try to write about some of these titles:

America during the Great Ice Age
The Journey of a Molecule of Water
The Story of the Mississippi River Delta
The History of the Colorado River
Life in the Days when the Region of my Home was beneath the Sea
Caught in a Desert Sandstorm

4. Build a model or make a drawing to show the character of one wall of the Grand Canyon, following the drawing in Fig. 168. Indicate the different layers of rock by using different colored paints.

5. You may have read from time to time about the floods which cause hundreds of thousands of dollars' worth of damage

all over the world. Many of these floods are made more severe because of land erosion. See if you can find out why this is so and what our government is doing to prevent such floods. Are similar steps being taken in other lands?

6. Three of the old Egyptian gods were Osiris, Isis, and Apis. There is a legend about each of them and the story of the Nile floods. See what you can find out about them.

7. Every state has some natural, or scenic, wonders which may be explained in terms of the story you have read in this chapter. What has your state? Do you know its story? Perhaps you may want to write a well-illustrated story of the scenic wonders in your locality or your state and present it in class. Many states have some kind of state department of geology. You may get help from this department.

8. A few famous glaciers are mentioned in this chapter. There are some others. Find out about them and indicate on an outline map just where they are located. Does their location help to explain their origin?

9. The Mississippi River system is one of the largest river systems. Do you know how long it is? where it begins? which important rivers are a part of it? Look up some of this information. You may want to draw in this system on an outline map. Compare this map with one showing the regions that produce corn, wheat, cattle, hogs, and cotton. What relationships do you find?

Chapter XVI · How is the Surface of the Earth Elevated?

If you will think a little about the effect of erosion as you have seen it in various parts of the world, you will realize that there must be other forces of change. Although erosion is a slow process, in time it would wear down the entire surface of the earth. In fact it might even destroy the whole land area of the earth and bring all of it under the sea. Why doesn't this happen? In order to answer this question, we must study other forces that are producing changes on the surface of the earth.

While wind and water are wearing down the high places, forces within the earth are alternately raising and lowering the surface of the earth. High mountains are raised and worn down. Regions that were once high mountains and plateaus are lowered until the water of the sea spreads over them. These changes are still going on. The geologist interprets the changes of the past by the study of the changes going on today.

A. What Changes are brought about by Volcanoes?

Some of you have read *The Last Days of Pompeii.* Many of you have doubtless read in history something about a volcano called Vesuvius, in the southern part of Italy. It is illustrated in Fig. 180. Away back at the time of the birth of Christ this supposedly extinct volcano towered high above the towns of Pompeii and Herculaneum. It was considered perfectly harmless, however, for not even among the folklore, or stories handed down from generation to generation, were there any statements that the volcano had ever been active. People knew that it must have been an active volcano once, for its top was a well-developed crater.

Pompeii is visible evidence of volcanic disaster

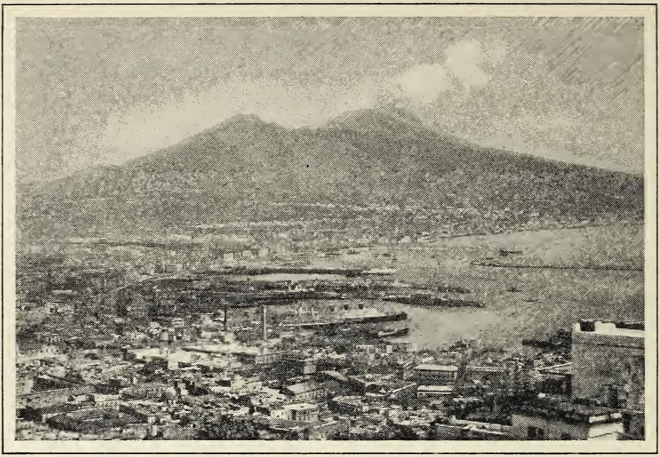

FIG. 180. Vesuvius is an Active Volcano

The Bay of Naples is in the foreground

A suggestion of volcanic energy came to the inhabitants of Pompeii in 63 A.D. The city and the surrounding region were visited by a severe earthquake that did great damage to the public buildings and the residences. In spite of this the people were not tremendously concerned, but immediately set to work to restore their buildings. The earthquakes did not cease, however, for through the sixteen years following 63 A.D. the region was subjected to numerous quakes which were more or less severe.

Finally on a hot summer day in August in the year 79 A.D., when the people of the towns in the valley were going about their business and while workmen in Pompeii were restoring the damage done by the various earthquakes, the earth began to tremble most severely. Through the crater of Vesuvius were hurled quantities of steam, hot stones, and ashes. Half the crater was blown away. Thousands of people were killed. Some were suffocated by the sulfurous gases, and some were crushed by mud and ashes. Others

FIG. 181. The Ancient City of Pompeii was buried in Hot Ashes as a Result of the Volcanic Explosion of Vesuvius

were trampled upon by the panic-stricken mobs as they rushed for safety. Pompeii was completely buried in hot ashes, while near-by Herculaneum was covered by hot mud and lava.

An account of the disaster is given by Pliny the Younger, whose uncle, Pliny the Elder, was killed while attempting rescue work during the disaster.

Little else was known about the lost city until nearly seventeen hundred years later, when a group of archæologists, men interested in the study of ancient peoples, decided to try to find the lost Pompeii. The site of the city was located from historical records, and the work of excavation began soon afterwards. Today, if you go to Italy, you may walk through the streets of Pompeii and look into the rooms of houses that were occupied two thousand years ago. There are paintings upon the walls and children's toys upon the floor. Dishes and food were found on dining tables where it was left when the residents

rushed for safety. As you look upon the pictures of ruins in Fig. 181, you realize that the landscape changed very suddenly for these people at the foot of Vesuvius!

Vesuvius has been in eruption several times

Time went on, and various less violent eruptions took place from the crater of the now active volcano. Between eruptions the volcano, to all appearances, was peaceful once more. Grass and trees had time to grow. Italian peasants who had never heard of the cities of Pompeii or Herculaneum had built homes at the foot of the mountain and had planted vineyards upon its sides. Then once again, in 1631, the earth began to rumble and tremble. This time there was a tremendous explosion, and the volcano began to pour forth lava, or melted rock. Another little village was buried.

Vesuvius is still active

The volcano has been active ever since, and at intervals lava has flowed down its sides, leaving black ridges. A period of a few years of quiet has been followed by a period of fresh activity. Thus the earth has been built up around the volcano. The last serious eruption took place in 1906. Tonight, if you were in Italy in sight of Vesuvius, you would see clouds of vapor rising from the crater, lighted by the intense heat from within. If you should climb to the crater's edge and look down into it, you would see the mass of molten lava bubbling away and occasionally spurting up, throwing stones and ashes into the air. The guides of Naples point to the smoking crater of the mountain and say in broken English to the tourist, "He's a bad fella."

Much of the region surrounding Vesuvius shows evidence of volcanic activity. In the Phlegræan Fields, west of the city of Naples and about thirty miles from Vesuvius, are several old craters. Of these probably the best-known is Solfatara. This was in active eruption in the twelfth century. Today the visitor to this region may walk over the hardened surface of the old crater. The earth is warm

under his feet, and in the crust are some openings through which one may see boiling-hot lava, as in Fig. 182.

Near Solfatara, on the Bay of Naples, are the ruins of the ancient temple of Jupiter Serapis, built about 400 B.C. by the Greeks who had come to Italy. Three marble columns still stand among the ruins. In the interval of some two thousand years the floor of this temple has been covered with water from the bay, which stood about the columns to a depth of eighteen feet. The floor later rose again. Now it is at about the same level as the water in the bay. This elevation and sinking took place slowly, but the evidence of the change is very convincing. What is it? you may ask. There is a clam in the Mediterranean Sea that will drill small holes in limestone. An inspection of the ruins of the temple shown in Fig. 183 reveals borings in the marble columns eighteen feet above the present level of the water. How did these get there? They must have been made during a time when this part of the column was under water. The level of the earth's surface in this volcanic area has certainly changed since the Greeks settled there nearly twenty-four hundred years ago.

Some regions have sunk beneath the sea and have risen again

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FIG. 182. The Region surrounding Vesuvius is One of Volcanic Activity

These tourists are visiting the Phlegræan Fields

Mount Etna is on the island of Sicily, about two hundred miles south of Vesuvius. During the period of its activity it has built a pile of lava and ashes that is now more than

ten thousand feet high. It has been active at intervals for at least twenty-six centuries. In an eruption in 1892 the lava which poured forth was hot enough (1900° F.) to melt iron.

Fig. 183. Borings in the Marble Columns of the Ancient Temple of Jupiter Serapis furnish Evidence that this Region was at One Time under Water

Stromboli is between Vesuvius and Etna, about a hundred and fifty miles from Vesuvius. It has been active since ancient times and has built up a mountain three thousand feet high. Violent eruptions are not common, but its activity is nearly continuous. Steam issues from the crater. When it condenses it reflects the light of the flowing lava beneath. Because it is usually visible at night, Stromboli has been called since early times the "Lighthouse of the Mediterranean."

This particular region of Italy is not the only one in the world which reveals volcanic activity today. There are active volcanoes in Alaska, Mexico, South America, Africa, Japan, Iceland, and on many islands, especially in the Pacific. The United States has one active volcano, Mount Lassen, in California. Volcanoes are not distributed all over the earth, but are found only in certain regions. Locate these regions on the map in Fig. 184. Many of the highest mountain peaks

FIG. 184. There are Active Volcanoes in Many Different Parts of the World Today

Are you familiar with any of those indicated on this map?

in North America, including Shasta, Hood, Adams, Baker, and Rainier, are extinct volcanoes. You might wish to check Fig. 184 to find which of the volcanoes shown are extinct and which are still active. From all the evidence we have, it is plain that almost every part of the world has had active volcanoes at some time in its geologic history.

Active volcanoes are found in many regions

B. What are the Conditions within the Earth which cause Volcanic Disturbances?

The forces of volcanic action have played an important part in building up the land. What causes volcanic eruptions? How is it that a volcano may become extinct? There is still a great deal to be learned about volcanoes, but from what is known a good explanation may be made of their causes. In order to answer these questions, however, it is necessary to know something about the interior of the earth.

How may one find out anything about this? One source of information is in the story of earthquakes, about which you will learn more just a little later on.

When there is an earthquake the tremors, or shocks, travel outward as waves in every direction from the disturbance. It has been found that the waves through the center of the earth travel faster than the waves along the surface. It has been proved that such waves travel faster through elastic material. It is supposed, therefore, that the interior of the earth is more elastic than the surface. Evidence suggests that the elasticity of the matter through the center of the earth is about that of steel.

There is additional evidence that supports this same conclusion. Two different methods have been used to determine the density of the earth. (Density means times heavier than an equal volume of water.) Both of these methods indicate that the average density is about 5.5.

The density of surface rock is only about 2.7. If the surface density is 2.7 and the average density is 5.5, the density of the earth's interior must be greater than 5.5. Can you see why? These observations of the rate at which tremors caused by earthquakes travel through the earth and of the differences in density and elasticity between the surface rocks and the earth's interior are the bases for conclusions concerning the interior of the earth.

The interior of the earth is denser than the surface

What would a cross section of the earth look like according to these beliefs? There are, of course, no direct observations about the interior of the earth, but many indirect observations furnish information about it. Study Fig. 185. Most of the surface of the earth is covered with sedimentary rock, such as shale or sandstone, formed from the deposits of sediment when the region was covered with water. In some places this is as much as two miles thick. Beneath the sedimentary rock is found igneous rock, extending downward and gradually increasing in density. This igneous rock, once molten, has cooled and hardened. In some places where the covering of sedimentary rock is lacking, some form of igneous rock, such as granite, is at the surface. At a depth of a thousand miles the rock contains a large amount of metallic iron. At greater depths there is more and more metallic iron. The interior of the earth is believed to be a core of iron or iron and nickel, having the firmness of steel and about four thousand miles in diameter.

A solid crust of rock covers most of the earth

The interior of the earth contains much iron and nickel

With this picture in mind consider another question. Is the interior of the earth hot or cold? Much evidence points to the fact that it is hot. Some of this evidence is familiar to you. Mine workers are well aware that the temperature in deep mines is higher than the temperature at the surface. In the deep

The interior of the earth is very hot

copper mines of Michigan and in some of the gold mines of the African Transvaal region the heat is extremely uncomfortable. From this and other evidence scientists estimate that the average increase in temperature is about 1° F. for every 33 feet in depth. If this rate of increase continues to a depth of 60 miles, the temperature should be about 9600° F.

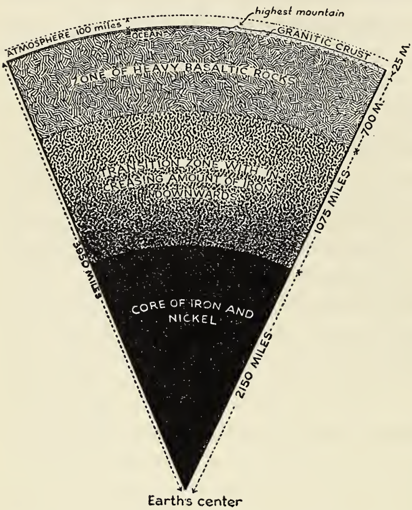


Fig. 185. As a Result of Study and Observation, Scientists believe a Cross Section of the Earth would look like This

Finally, one more question might be asked. Is the interior of the earth liquid or solid? Certainly the temperatures found deep within the earth are far above the melting point of rock. This would lead one to decide that the earth's core is liquid. Remember, however, the great pressure exerted upon the interior of the earth by the weight of the masses of rock above. What conclusion can be drawn? Scientists believe that, even though the rocks are hot enough to melt, they are kept in solid form by the tremendous pressure.

All these facts can now be put together and be interpreted by the theory held by scientists in regard to volcanic action. If for any reason the pressure at the surface of the earth is reduced, the hot flexible rock in the interior moves toward the position of less pressure. If there is a crevice in the solid rock, the hot rock underneath may flow up as lava toward the surface.

Volcanic action is frequently associated with the formation of mountains. In this process the surface layer of rock is broken, pressure is released on the hot flexible rock beneath, and it begins to flow toward the break. The immediate cause of the eruption may be due to steam generated when water, trickling down through the broken surface rock, meets the hot rock beneath. You may recall from previous experiences something of the powerful forces associated with expanding steam. When the steam pressure becomes strong enough, it blows out through the weakest place. As it escapes, the steam carries with it molten lava from deep down in the earth.

When surface pressure is reduced, the plastic interior flows toward the region of less pressure

C. What happens when the Earth Quakes?

To a person who has experienced an earthquake, there is perhaps no more fearful example of the powerful forces which are at work within the earth. The solid ground shakes; tall buildings sway, and sometimes topple in a jumbled mass of steel and masonry; gas and water mains are ripped apart; telephone and telegraph communication is stopped. Within a few minutes a community of thousands of people and hundreds of beautiful buildings may become a region of utter ruin, isolated and cut off from the rest of the world. Look at the wreckage in Fig. 186.

Fortunately such damaging earthquakes are rare. Earthquakes of less violence are not rare. Every year there may be thousands of them. Most of these are slight and would not even wreck houses if there were any at the point where the earthquakes occur. How, then, you may ask, is it known that there are such earthquakes? Interest in this question has led to much study. For this study, carefully designed instruments have been made on which the effects of earthquakes may be registered.

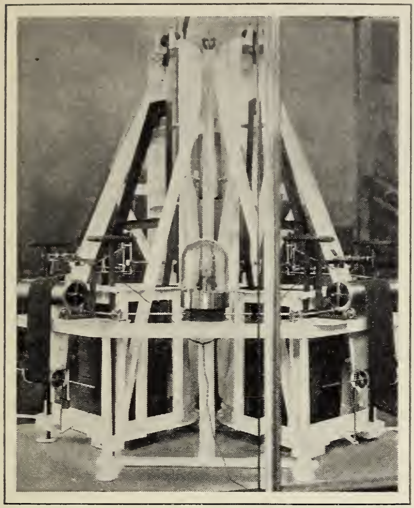
There are thousands of slight earthquakes every year

Fig. 186. An Earthquake often does Severe Damage

This was once a school building

A seismograph records earthquakes

In many of the observatories located in different parts of the world is an instrument called a seismograph. This is illustrated in Fig. 187. In its simplest form a seismograph consists of two parts: a heavy pendulum so hung that it tends to remain stationary even when the earth trembles, and a base anchored on the solid rock of the earth. During an earthquake the base moves with the rock to which it is anchored. On the base is mounted a cylinder, or drum, turned by clockwork. As it turns, a needle or pen connected to the pendulum draws a line on the surface of the paper covering the drum. If there are no tremors, the line drawn by the pen is smooth. If the earth quakes, however, the shocks are passed on through the base to the drum carrying the paper. The result is a jagged line, as illustrated in Fig. 188. Notice the smooth line suddenly broken as the instrument records an earthquake.



A. M. N. H.

Fig. 187. A Seismograph registers Earthquakes

This instrument is the largest seismograph in the United States. It is in the American Museum of Natural History, New York City

A seismograph is very easily affected. An earthquake in Japan may be recorded thousands of miles away in the United States, France, Germany, or England.

In December, 1932, an unusually severe earthquake shock was recorded upon instruments in the United States as well as in other parts of the world. A comparison of the records showed that the center of the disturbance was in a distant province of China. Forty-seven days later news came by way of eyewitnesses that several hundred people had perished in an earthquake in China on the day that the disturbance was registered on the seismographs located in laboratories all over the world.

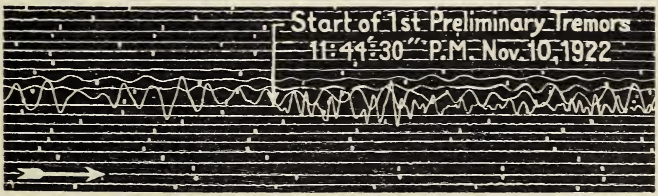


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Fig. 188. The Record of an Earthquake on the Seismograph in Fig. 187

Can you find where the earthquake started? The shocks recorded on the right-hand side of the strip occurred within a period of about four minutes

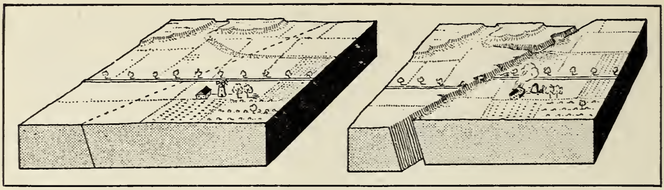


FIG. 189. Sometimes during an Earthquake the Earth may crack and slip along the Crack as shown here

What happens during an earthquake? During each trembling of the earth some change takes place in the earth's surface. Some places may be raised, while others may be lowered. A crack, or a *fault,* may be formed, or a section of the earth may slip along the crack that had formed at an earlier time, in a manner shown in Fig. 189. Sometimes the fault is a vertical one, as shown in Fig. 190. A section of the earth slipping along a fault causes the jar that is called an earthquake. This movement continued through long periods of time is one of the causes of mountains.

Earthquakes are common where high mountains and deep oceans are close together

Where violent earthquakes are common, high mountains and deep oceans are usually close together. The deepest known place in the oceans is just off the shore of Japan, and eastern Japan is the scene of frequent earthquakes. Many earthquakes occur in regions of present or of recent volcanic activity. Earthquakes result from comparatively small changes on the earth, but they are changes that take place suddenly. The character of the changes contributes to our understanding of volcanoes and to other processes of mountain-forming.

D. What causes the Surface of the Earth to Fold?

If you have ever traveled through the Rockies or other equally impressive mountain chain, you may have found running through your mind the question of how they were

U. S. Geological Survey

Fig. 190. A Crack, or Fault, may be formed during an Earthquake

Notice how the slipping of the rock has caused the layers to be put out of their proper position

formed. If all mountain peaks were volcanic in origin, you might be able to answer your own question. You could decide that the peaks developed as lava flowed upward through the volcanic craters. But it is not as simple as this. The great mountain chains, such as the Rockies, the Appalachians, and the Himalayas, are not volcanic in origin. They were formed when great folds occurred in the earth's surface. Study Figs. 191 and 192. One is a cross section through a typical volcano, and the other through a mountain range. Can you see any differences? Notice the circular formation of one and the folded layers in the other. How is it possible, you may ask, for the surface of the earth, which seems a rigid mass of material, to fold?

Some mountain peaks are formed by the folding of the earth's surface

You may get an understanding of this process if you will recall some of the things you have learned about the crust of the earth and of the conditions beneath that crust. At the same time keep in mind some of the forces which are operating upon and within the earth.

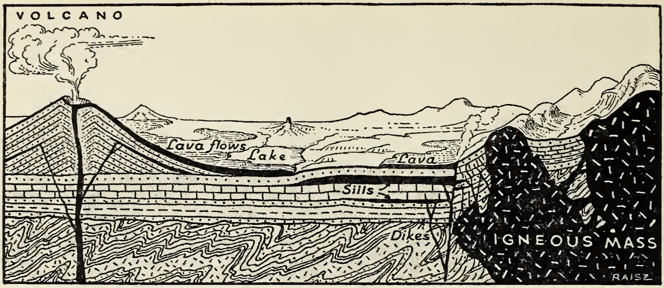


Fig. 191. A Cross Section through a Volcano reveals a Different Type of Rock Formation from One through a Mountain Range

Contrast this picture with Fig. 192. Notice the dikes and sills formed from lava which has spread between layers of rocks. Notice, too, how some of the molten matter has hardened and formed an igneous mass

The crust of the earth is not everywhere equal in density

What would be the result of such conditions? One of the theories of mountain formation is based upon the idea that the pressure of the earth's crust upon the hot interior is not always the same. Suppose that a certain region is covered with mountains. At the base of these mountains and extending over a large area is a vast body of water. At first it would seem that the pressure of the land area upon the interior of the earth would be much

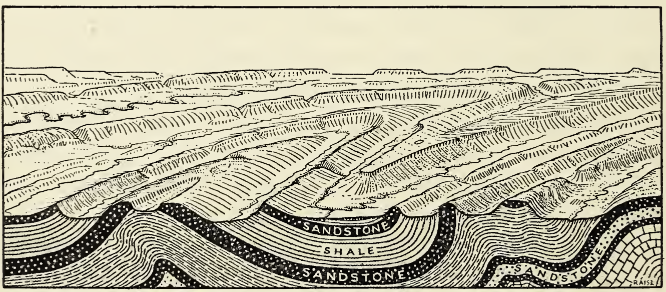


Fig. 192. Folds are Caused by Changes in Pressure of the Rocks Above

Can you explain why sandstone and shale may be found even in mountain regions?

greater than the pressure of the water area. But this is not so, because the rock which forms the bottom of the ocean is denser than that which forms the mountains. Thus the land and the water areas of the earth, although unequal in height, tend to exert an equal pressure upon the softer rock beneath. But the pressure does not remain equal. Consider the forces which are at work upon the mountains. Erosion gradually wears them down, and rivers carry the sediment into the ocean. As more and more sediment is deposited, the pressure of the water area becomes greater than the pressure of the land area. This may be shown by a diagram such as Fig. 193.

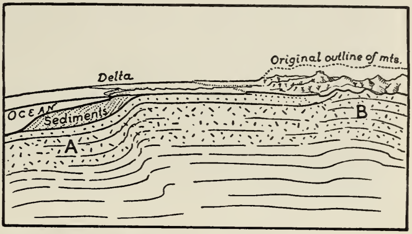
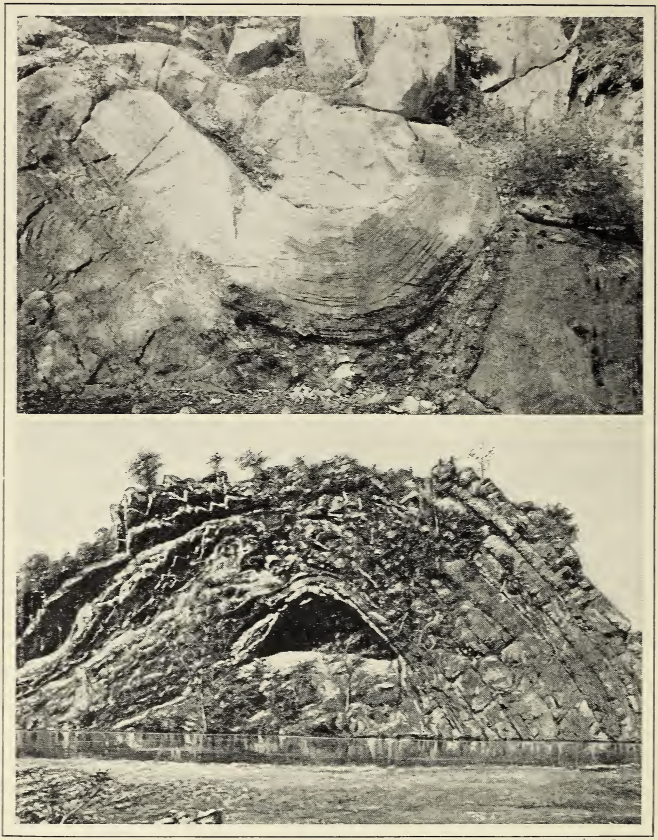


Fig. 193. As Mountains are worn down and carried to the Ocean as Sediment, the Pressure changes on the Rock Beneath

Notice how the mountains have been worn away, and how the sediment has been deposited at the mouth of the river. As erosion continues, more and more sediment will be deposited. In time the pressure of this sediment will cause the rock at *A* to sink, and this in turn will raise the region at *B*, forming new mountains

What should you expect to happen under such conditions as those just mentioned? Where the pressure is less, the hot material of the earth's interior expands and causes the surface to rise. Thus a range of mountains might rise slowly, pushing up the sedimentary rocks over the surface, and other regions of the earth might slowly sink. In order to see this picture properly, you must consider it in terms of many millions of years. In the course of time the mountains are again worn down and deposited as sediment at the bottom of the sea. Thus the pressure is continually changing, and land surfaces are rising and sinking. New mountains are formed. This cycle of changes is repeated time and time again.

Unequal pressure causes the surface of the earth to rise and fall



U. S. Geological Survey

FIG. 194. Layers of Sedimentary Rock often show Tremendous Folds

The rock formation at the top is called a syncline; that at the bottom, an anticline. Look up the meaning of these two words

These theories will help you to explain what you see as you travel through mountains. There are enormous folds, as shown in Fig. 194. There are regions in which folds and breaks are clearly shown. You may trace the folds by an examination of layers of sedimentary rocks. These are so

W. T. Lee, U. S. Geological Survey

Fig. 195. In Some Cases the Layers of Sedimentary Rock stand almost Upright

This scene is from Thompson's Canyon, Colorado

called because they were formed of the deposit of layers of sediment which later hardened. It is obvious that they must have been horizontal when they were formed. Yet in the mountains you may see them folded at steep angles. In some cases they are standing nearly upright. Look at Fig. 195. The walls of this canyon consist of nearly upright layers of sedimentary rock. Evidently the crust of the earth at some time has been folded, crushed, and broken.

Sedimentary rock was formed in horizontal layers

As this change takes place, cracks, or faults, are formed. These offer channels through which the melted matter from far down beneath may flow up toward the surface. Flow in a crack through the layers of rock forms a dike. Flow between the layers forms a sill. Can you find these in Fig. 196? As the melted matter comes nearer the surface, it hardens and forms igneous rock. Sometimes the soil which covers the dikes and sills is worn away, and these

U. S. Geological Survey

Fig. 196. Sills and Dikes are formed as Melted Rock Hardens. Compare these Photographs with Fig. 191

The sill (to the left) and dike (to the right) were exposed as the soil was worn away

formations may be seen as in Fig. 196. Granite is igneous rock that solidified below the surface. Granite shows on the surface only in regions in which the surface layers under which it formed have been worn away by erosion. Pikes Peak and other high mountains are masses of granite which have pushed up from beneath. The sedimentary rock that once covered it was softer than the granite. Therefore much of it has been worn away.

Granite is igneous rock, formed by heat

There are many regions in which melted rock has flowed nearly or entirely to the surface. At the surface the rock cools and hardens quickly. This rock which cools quickly is called basalt. It differs in appearance from granite, which has cooled slowly. Along the Columbia River, in Washington and Oregon, there is such a flow. The melted rock rose to the surface and spread over an area of some two hundred and twenty-five thousand square miles. The average thickness of this layer is about five hundred feet. Look at Fig. 197 showing a lava flow in the northwestern United States.

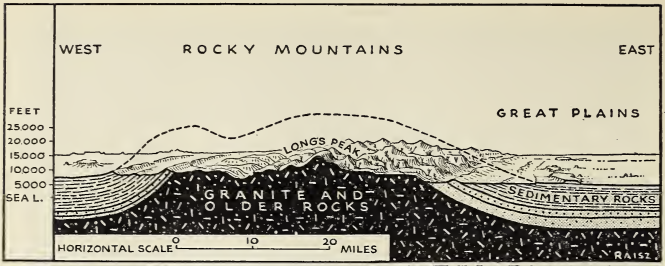
© Brubaker Aërial Surveys, Portland, Oregon

FIG. 197. There are Many Regions in which Melted Rock has flowed to the Surface

This airplane view shows such a lava flow at Davis Lake in Oregon

Mountainous regions show great geologic changes

If you will consider the things you have just learned, you will realize that any mountainous region is one that has undergone enormous changes. Consider the present Rocky Mountain region. At one time this region was beneath the sea. A thick layer of sedimentary rock formed there from the sediment carried to the sea by the hundreds of rivers which emptied into it. These sediments formed layers of shale, sandstone, limestone, and other kinds of rock. In the course of geologic time, pressure from the hot rocks beneath raised this region until the land surface was above the level of the sea. Such elevation may have occurred without folding or faulting. Level and fertile plains were formed. As time went on, continued pressure from beneath raised the surface higher and higher, and folding and faulting did occur. Of course these changes took place so slowly that they could not have been noted by close observation, even if anyone had been there to observe them.



After W. T. Lee, U. S. Geological Survey

FIG. 198. A Cross Section East and West through Longs Peak in the Rockies show how Sedimentary Rocks have been Worn Away

How does the formation of these mountains differ from those in Fig. 199?

A cross section east and west through Longs Peak, in the Rockies, shows how the sedimentary rocks there have been worn away from the top of the peak. Longs Peak is now more than fourteen thousand feet high. The dotted line in Fig. 198 shows that it would have been at least twenty-five thousand feet high if the forces of erosion had not worn the top away. As you look at this mountain, you see evidences of enormously complex changes, and you see evidences that these changes are still in progress.

The formation of mountains is a slow process

The elevation of mountains is a process that goes on through millions of years. While they are rising, running water and other forces are at work wearing them down. They may at times be worn away faster than they are formed.

Let us consider another typical example of mountain formation. A cross section through the Appalachian Mountains is shown in Fig. 199. This shows how the mountains were formed by the folding of sedimentary rock and how the tops of the mountains have worn away. The Eastern mountains are much older than the Rockies. Evidence indicates that the region of the Rockies was beneath the sea during much of the time that the Eastern mountains were forming.

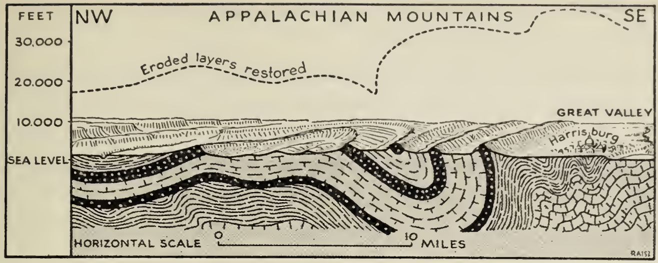


Fig. 199. A Cross Section through the Appalachian Mountains shows that they were formed by the Folding of Sedimentary Rock

What evidence is there that these mountains are older than those in Fig. 198?

There is also evidence that the region of New York City was once a region of high mountains comparable to the Rockies. Fig. 200 shows a cross section through the island of Manhattan, on which part of New York City is located. In this region are found some of the oldest rock formations. The island itself is composed of folded and compressed rock formed during the first era of geologic time. Today nothing but the bases of these mountains remain, for the peaks have been worn down until they are nearly at sea level. If you question the geologist concerning the origin of the ancient rocks, he will tell you that

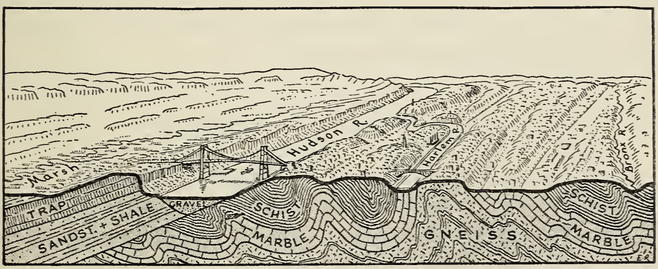


Fig. 200. The Region of New York City was once a Region of High Mountains Comparable to the Rockies

Notice the many different kinds of rock shown in this cross section through Manhattan Island and surrounding territory

they are composed from sediments formed by the erosion of still more ancient rocks.

Perhaps after reading this section you feel that evidences of mountain and rock formation are to be found only in mountainous regions and only by someone highly trained in geology. Neither of these suppositions is correct. With the knowledge you now have you can find many illustrations of the forces about which you have learned. Further, these illustrations may be found in nearly every region of the United States. If you live in a mountainous region, they are quite obvious. If you live in a region that is not mountainous, there is still evidence to be found. Banks of rivers may be cut away, showing a cross section of layers of sedimentary rock. Even in the city you may see evidence of these changes. Have you ever watched the work upon the foundation of a large building as it was sunk into the ground? Frequently, after a few feet of earth are removed, masses of solid rock appear. These are blasted out. In the sides of these excavations you may find convincing evidences of the play of powerful forces.

Evidence of rock formation may be found in any locality

Every rock carries within itself evidence of the conditions under which it was formed. In your field trips you will learn to recognize this evidence and from it to learn some of the stories of the rocks.

E. How Old are the Rocks?

Another way of asking this question would be, "How old is the earth?" Regardless of how it is asked, the question is still a difficult one to answer. As you look at huge mountains, vast plains of rich earth, and deep rivers, you feel that they represent long periods of time during which many natural forces have been at work. But how long? How can one find out?

Scientists have tried in many different ways to find an answer to this question.

One scheme which has been used is that of trying to estimate how long it has taken certain bodies of water to become salty. As you know, when rain falls it is not salty. You know also that the salty taste of the ocean waters comes from certain substances dissolved in the water as it flowed over the land. This addition of salt, as you can see, must be very slow. By this process scientists have estimated the age of the ocean as more than three hundred million years.

Salt is deposited in water slowly

Within the last few years science has attacked the problem in a different way. From experiments in laboratories it has been found that the element uranium slowly breaks up into helium, which is a gas, and lead, which is a metal. If you will remember that small quantities of uranium are present in igneous rock today and that in all probability this was equally true when these rocks were formed, you can understand this new method of determining the age of the earth. It is possible to make very delicate measurements of the rate at which the breaking up of uranium takes place and to identify the lead that is formed. When the amount of lead formed since the rock became solid is known, together with the rate at which the lead collected, the length of the interval during which the lead was forming may be determined.

The rate at which uranium changes into lead tells the age of the rock in which the uranium is found

What is the result of all these different means of measurement that science has used? Increased knowledge has meant a steady increase in the estimated age of the earth. In ancient times learned men calmly worked out the very year in which the earth was formed — in some cases to the month, day, and hour. Later on, however, it was found that these were merely guesses, and new estimates were made. Gradually these estimates were length-

The estimated age of the earth has increased tremendously

ened. As late as 1897 a famous British scientist estimated the age of the earth as somewhere between twenty and forty million years. Today the estimate is much larger. Upon the basis of the uranium method, granite rocks in several regions where measurements have been made are believed to be more than a billion years old. It is plain that no one can accurately say just how old the earth is. One thing, however, is sure. When you look at a piece of granite, you are looking at something extremely old.

Today the age of the earth is estimated to be more than a billion years

F. What are the Main Divisions of Geologic Time?

As you can easily imagine, many things have happened upon the face of the earth during the long time which has passed since it first formed. In history you usually identify such happenings by date. You say, for example, that Columbus discovered America in 1492 or that the Revolutionary War began in 1775. This is easy, for the recorded period of history is not long. But suppose that you tried to identify geologic happenings by exact dates. It would be rather difficult, wouldn't it? Even if you knew the exact date, imagine saying that a certain thing occurred in the year 1,757,800 B.C. or 375,859,966 B.C. or, even worse yet, in 1,745,738,756 B.C.! It's almost impossible, you say. And so it is. It is wholly impossible to tell so exactly when an event occurred in the far-distant geologic past. But you can often say with certainty that one event preceded, or occurred before, some other event. Geologists, like historians, have divided the history of the earth into periods. While history uses three periods, — ancient, medieval, and modern, — geology uses five. In geology, the periods are called eras. These, like the periods of history, are defined by the things that took place. Let us mention these eras briefly, beginning with the oldest. You will learn a great deal more about them later.

There are five geologic periods

1. *Archæozoic.* During this era of the oldest rocks a great mountain system was formed which extended from Labrador to Minnesota. There may have been living things on earth during this time; but, if so, they were very simple forms. This era lasted four hundred million years or perhaps considerably longer.

2. *Proterozoic.* During this era the iron ore of the Lake Superior region was deposited. During part of the era most of the North American continent was under water. The oldest evidences of the action of glaciers are found in Proterozoic rock. At the end of the era the outline of the continent was similar to but not exactly like what it is today. The era lasted probably in the neighborhood of three hundred million years.

3. *Paleozoic.* The Pennsylvania and Mississippi Valley coal beds were formed, also the Appalachian Mountains. There were fishes and reptiles and many kinds of plants. Glaciers appeared near the end of the era. This era lasted probably four hundred million years.

4. *Mesozoic.* The Palisades of the Hudson and other volcanic formations appeared in the eastern section of the United States. The Rocky Mountains began to rise. Dinosaurs lived and became extinct. There were birds, reptiles, small mammals, and many kinds of flowering plants. This era lasted about a hundred and twenty-five million years.

5. *Cenozoic.* There was considerable volcanic activity in western North America, and the Rockies continued to grow. The Alps and the Himalayas were formed. Glaciers again covered a large section of the earth, and, geologically speaking, these glaciers have only recently disappeared. We live today in this era. About sixty million years of it have passed. All the higher animals and plants, including man, have developed during this era.

As you try to carry yourself back in imagination over those eras, you find that even the meaning of the numbers which indicate their length is difficult to comprehend.

Do not try to remember the exact number of years represented by each of the periods. Merely keep in mind that during this tremendous length of time all the changes on the surface of the earth which you have read about in this chapter and the preceding chapter have taken place. As a

result of your thought about these forces — glacial action, running water, wind, volcanic action, and earthquakes — and of the knowledge that they have been going on all over the earth for millions of years, perhaps you will now have a different answer to the question How old is the earth?

There are forces which operate to raise some regions of the earth and lower others. These forces may be seen in such features of the environment as volcanoes, earthquakes, and the folding of the earth's crust. These forces explain the formation of mountains, plains, and oceans. It is evident that the earth is very old.

Can You Answer these Questions?

1. What is the origin of the rocks of which Vesuvius is composed?

2. What evidence is there that some of the land regions around the Bay of Naples were at one time under water?

3. What conclusions about the interior of the earth may be drawn from observations made of earthquakes?

4. What evidence is there to support the belief that the average density of the interior of the earth is greater than that of the rocks which compose the earth's surface?

5. If you could examine a cross section of the earth, what changes in composition should you observe as you moved from the surface toward the center?

6. What evidence is there that the interior of the earth is hot?

7. What is one explanation of volcanic action?

8. How is a seismograph mounted, and how does it record earthquakes?

9. What is a fault? What relation has this to earthquakes?

10. Can you explain how the pressure on the earth's interior changes from time to time and from place to place?

11. How do the rock formations within an extinct volcano differ from the rock formations of a mountain range?

12. What is a difference between sedimentary rock and igneous rock?

13. What are dikes and sills?

14. What evidence is given in this chapter that mountains are being worn down?

15. This chapter tells of two ways in which scientists have tried to estimate the age of the earth. What are they? How have they been used? Which do you think is the more accurate?

16. What are present estimates of the age of the earth?

17. What are the main eras of geologic time? What are some of the identifying features of each?

Questions for Discussion

1. Why do you think there are not more active volcanoes in the United States?

2. How do you think the scientists determined the geologic eras of the earth as we know them today?

3. Which do you think is the more rapid process, the raising of the surface of the earth or the lowering of the surface of the earth?

4. During an earthquake is the surface of the earth raised or lowered or both?

5. What is meant by the statement that every rock carries within itself evidence of the conditions under which it was formed?

6. Why do you think that the present estimated age of the earth is so much greater than the estimated age given only a few years ago?

Here are Some Things You May Want to Do

1. See what you can find out about some of the famous volcanoes of the world, such as Mont Pelée, Mauna Loa, and Cotopaxi. Are they active now? Locate them on a map, and compare this map with Fig. 184. Are all volcanoes within or near a region of great volcanic activity?

2. A short time ago the United States set aside some additional territory as a national park. This region is called the Valley of Ten Thousand Smokes. See what you can find out about it. The National Geographic Society issued a special book about this region. Perhaps this book is in your library.

3. Look up in a dictionary the names used to indicate the various eras of geologic time. See where these words came from and what they mean.

4. People of long ago knew little about the processes going on within the earth. They explained these processes as the acts of certain gods. Prepare a class report on some of these ancient beliefs. As a beginning, look in some book of myths for information on Vulcan and the Titans.

5. Is there any evidence in your locality of the elevation of the earth? Are there any rocks, such as those in Fig. 194 or Fig. 195, that were certainly at one time beneath the sea? Where are they? How old are the rocks in your region? All these questions and others may be answered by information gathered on a well-planned field trip. The results might be organized in a class exhibit on "The Geologic History of our Region."

6. Find out from your state geologist whether a geological survey has been made of the region in which you live. If such a survey has been made, you may be able to get from the United States Geological Survey, Washington, D.C., a geological map showing conditions of your locality or of some place near you.

Chapter XVII · Have the Changes on the Surface of the Earth caused Changes in Climate?

Back in the year 1888 a large Eastern city experienced a blizzard. It still marks a milestone in the memory of older inhabitants. The vividness with which this storm is yet remembered is evidenced by the experiences of Stewart, a boy in one of the schools there today. After a two-day fall of snow one winter he came in from play to find his grandfather sitting by the window. "Say!" said Stewart, who had been tramping through high snowdrifts for several hours. "This is some snow, isn't it?" His grandfather looked at him without enthusiasm. "You call this snow?" he said. "Why, son, you don't really know what snow is! Now back in '88 — " And then he continued with a story of people's climbing in over snowdrifts which reached to the second-story windows, of office workers marooned overnight, of milk and newspaper deliveries held up for days, and of horse cars and stagecoaches abandoned in the streets. "Yes, sir!" he finished. "There was snow in those days!"

Stewart's experience may be your own if you have older people in your family. Regardless of how much it may snow or rain, they are sure that it cannot compare with conditions in the past. Sometimes they just forget that they were youngsters then and that everything looked different to them. *Knee-deep* to a child may be only ankle-deep to his father! At other times people are convinced that conditions really were different and that we have much milder weather these days than they had as children. If you ask them how this is possible, they have several answers. Occasionally they will admit that they do not know; sometimes they will explain that the sun is cooling, that the Gulf Stream is changing its course, or that the inclination of the earth's axis is changing.

Fig. 201. The Winter of 1888 is still Vivid in the Minds of Many People

Do we still have snowstorms as heavy as this one?

From your own experiences you may remember that more or less snow fell last year than the year before, that last spring was the rainiest spring you had known, or that last summer was much hotter than the one a year before. Perhaps you too feel a little doubtful about the whole thing and want to know whether the climate is really changing. Before you definitely make up your mind, remember that most people are likely to remember the strange and unusual things in the environment. This applies to weather changes. Months may go by without any sudden changes. Some days are cool; some are hot. But suddenly a spell of unusually hot or cold weather comes. This makes a great impression upon people, and from that time on they use that unusual condition as something by which to measure the rest of the weather. If you recognize that these are errors in thinking rather than real changes either in weather or climate, you may feel even more doubtful about climatic changes.

If you asked a scientist for his opinion, he would say that no perceivable climatic changes seem to have occurred during the last few hundred years. The weather in the temperate zone changes from day to day, and a dry day follows a wet one. The years may vary a little in amount of rainfall or degree of heat. The average temperature and rainfall over periods of years, however, seem to remain about the same. The same statement, he would add, applies to the other factors which make up climate. Accurate records of weather conditions through more than a hundred years furnish the evidence for this statement. Is there any other evidence?

Great climatic changes have not taken place over short periods of time

A record of climatic conditions through the last few thousand years is found in the big trees of California. By observation of the annual rings one may tell whether a year was favorable or unfavorable for growth. It is obvious from this long record that some seasons have been more favorable for growth than others. There are some years in which relatively thick rings were formed. These were probably warm seasons of most abundant rainfall. The rings formed in other years are thinner, indicating lack of rainfall. There are evidences of intervals during which one dry season followed another for several years. There are other intervals that show several wet years in succession. These intervals of wet and dry seem to follow each other in regular cycles. The differences between wet and dry years were certainly not great, for through all the years the trees continued to grow. These trees were growing in what is now California at the time when the civilization of the ancient Greeks was developing, more than three thousand years ago. Although climate may have varied somewhat during this interval, the climatic conditions under which these trees live today are probably about the same as when their growth began.

A record of climatic conditions may be found in the big trees of California

Deutches Museum, Munich

Fig. 202. The Scientist and the Artist combined their Knowledge to produce this Imaginary Picture of Life in the Region of the Pennsylvania Coal Beds during the Paleozoic Era

Does this mean that the climate has never been different from what it is today or that it never will be different? Not at all. Climatic changes have without doubt taken place in the past and are probably still going on. They are so slow, covering thousands if not millions of years, that we cannot see the changes as they take place. If instead of looking at a period of one hundred years or perhaps of a few thousand years, one considers the whole stretch of geologic history, the effect of climatic changes may be observed very clearly.

A. What Evidence is there of Climatic Changes?

A visit to the coal mines in Pennsylvania or in Illinois, together with a study of the origin of the coal, convinces one that the climate of that region, back in the Paleozoic era some two or three hundred million years ago, was much warmer and wetter than it is today. Look at Fig. 202.

The New York Botanical Garden

Fig. 203. These Plants (called Cycads), growing in the New York Botanical Garden, are Distant Relatives of those which flourished in the Warm, Moist Climate of the Paleozoic Era

Coal beds are evidences of climatic change

Coal beds are the remains of a dense vegetation that once grew in swamps. Covering the greater part of this marshy land were tangled forests of fast-growing plants. These plants were big enough to be called trees, but in form and construction they were more like our ferns and club mosses than like our trees. Perhaps you know the small plant called horsetail. There were trees in those ancient forests almost exactly like what these horsetails would be if they were enlarged from six inches to sixty feet. There were trees like huge club mosses — the kind we use for Christmas wreaths. At one time in the far distant past, palms similar to those now found in the tropics grew as far north as Greenland. Plants similar to these may now be seen in botanical gardens. Look at Fig. 203.

When these plants died and fell, they were buried beneath the shallow water. They did not decay as do trees

which fall upon the land. Other plants grew above them. In time these too died and fell upon the others. Time went on, and more plants fell. A thick soft carbon mass like peat was formed; but as the pressure became greater, the carbon mass became more compact. Soft coal was produced first. When the region of Pennsylvania was folded into mountains, some of this coal was pressed deep within the earth and under the influence of pressure, heat, and time became anthracite, or hard coal. For the vegetation to have been dense enough to form coal, the climate must have been warm and moist. Fossil markings in the coal reveal a plant life as luxuriant as that of an equatorial rain forest of the present. The vegetation which grew so rapidly and to such great heights simply could not exist, let alone flourish, in such a climate as that of Pennsylvania and Illinois today.

Besides, this condition of moist tropical climate must have been present for a very long time. It is estimated that some ninety thousand years were required to grow enough vegetable matter to form the coal beds of Pennsylvania. The coal beds of Colorado were formed during a more recent period. Coal has been formed at some place in the world through all the eras of geologic time and is forming in some small areas today. The largest deposits in the United States, located in the upper Mississippi Valley and in Pennsylvania, were formed during the Paleozoic era some three hundred million years ago.

Let us look at some other regions. Coal is also found on the antarctic continent, in Great Britain, and in Siberia. Coal-forming plants could not grow in these countries today. No flowering plants can grow on the dreary wastes of Antarctica. Obviously the climates of these regions have changed.

What other evidence is there? Recall the story you read just a short time ago about glacial action upon certain areas of the United States. These huge sheets of ice, as

you will remember, once covered the northern part of the United States, extending as far south as Long Island, New Jersey, Louisville (Kentucky), St. Louis (Missouri), Pierre (South Dakota), and the state of Washington. Today the glaciers of North America are confined to a few high mountain peaks. Obviously the climate of the United States is warmer today than it was during the ice ages.

Glacial action is evidence of climatic change

Along with this change in temperature have come changes in the amount of rainfall. You have observed that Great Salt Lake is much smaller today than it was several thousand years ago. It seems evident that the rainfall of this region is less today than at an earlier time.

There is abundant evidence, then, that great climatic changes have taken place, but there is no evidence that these changes take place fast enough to be discovered by ordinary measurements of temperature. The evidence at hand shows the results of changes that have taken place through thousands or millions of years.

B. Do Changes in the Sun help to explain Climatic Changes?

There is evidence from the record of the big trees and also from records of the Weather Bureau that small changes occur in cycles and that these cycles repeat themselves at relatively short intervals. A most commonly accepted theory for explaining these short cycles is the "sun-spot theory." Observations show that violent magnetic storms on the sun, as shown in Fig. 23, are accompanied by periods of increased magnetic and electrical activity upon the earth. These storms seem to occur in regular cycles, reaching greatest violence every thirty-five years. There seems to be a less well-marked cycle of eleven years, and possibly a longer period overlapping both of these. The

There seems to be a relationship between sun spots and conditions on the earth

rings of growth in the big trees of California furnish some evidence of a relationship between the rate of growth of these trees and these cycles of sun-spot activity.

An understanding of sun spots may help in long-range weather prediction

Dr. Charles G. Abbot, of the Smithsonian Institution, is the leading student of sun spots. As stated before, he is now making studies which he hopes will make it possible to prepare long-time weather forecasts. But this theory, whether adequate or not to explain small changes, is certainly not sufficient to explain the longer periods of alternate warmth and cold which caused the glaciers and coal beds of the country.

To help to explain the long-time changes some astronomers have suggested that the sun is a variable star and that it gives off more heat at one time than at another. This theory is without adequate support.

Evidently long-time changes in climate must be explained through other factors. What are they? To understand them you must recall our discussion of two subjects; first, the things which make up climate, such as temperature and rainfall; and second, the whole story of mountain and land formation. How are these two matters related? you may ask. In order to see this relationship and how it helps to explain our present problem, let us go back and discuss some of these factors a little more fully.

C. How does Water affect Climatic Conditions?

It is well known that places near the water, whether by the seashore or by a lake, enjoy more moderate climates than do places farther inland at the same altitude and latitude. That is, they are neither so cold in winter nor so hot in summer. This is one reason why the beach is a pleasant place to go to in summer.

The reason why places near the water change less in temperature from day to night and from winter to summer

is because the temperature of the water changes much more slowly than the temperature of a land surface. You may keep a ten-gallon aquarium in your schoolroom. The temperature of the air may change considerably from day to night in the room, while the temperature of the water will change but little. It requires about five times as much heat to raise the temperature of one gram of water one degree as is required to raise the temperature of an equal amount of soil, or earth, one degree.

Nearness to bodies of water affects climatic conditions

The effects of large bodies of water on climate may be seen today in the region of the Great Lakes. Madison and Milwaukee, in Wisconsin, and Grand Haven, in Michigan, are three cities equally far north and about equally distant from mountains. Each of these cities is very close to the forty-third parallel. From this similarity in latitude one might expect temperature conditions to be nearly the same in each of the three cities. Let us see if they are. The following figures are taken from Weather Bureau records:

	Average January Temperature	Average July Temperature	Average Yearly Range
Madison	17.0° F.	72.3° F.	55.3° F.
Milwaukee	20.5° F.	70.2° F.	49.7° F.
Grand Haven	24.1° F.	68.9° F.	44.8° F.

As you compare these figures and note the temperatures for various times of year as well as the average, you find some very interesting things. Notice the temperatures for January. Madison is the coldest city during this month and Grand Haven the warmest. In July, however, Grand Haven is the coolest and Madison the hottest city. These facts may be shown in another form by the following figures:

Highest July temperature ever recorded at Madison	104° F.
Highest July temperature ever recorded at Grand Haven . .	95° F.
Lowest January temperature ever recorded at Madison . . .	− 29° F.
Lowest January temperature ever recorded at Grand Haven .	− 14° F.

A study of the differences in temperature at these various cities for certain months of the year will show even more interesting contrasts. Look at the figures in the following table:

	Madison and Grand Haven	Madison and Milwaukee	Milwaukee and Grand Haven
Difference in average January temperatures	7.1° F.	3.5° F.	3.6° F.
Difference in average July temperatures	3.4° F.	2.1° F.	1.3° F.

Difference in average temperatures at Madison for January and July . . . . 55.3° F.
Difference in average temperatures at Milwaukee for January and July . . . . 49.7° F.
Difference in average temperatures at Grand Haven for January and July . . . . 44.8° F.

Which city has the most uniform temperature the year round? Which cities have the greatest difference in average January temperatures? in average July temperatures? What other differences can you find? What is the explanation for these differences?

The map in Fig. 204 may help. Notice the location of these three cities with reference to the Great Lakes. Grand Haven and Milwaukee are located on the shore. Madison is located inland. Now apply what you have learned about the effect of bodies of water upon temperature. During the winter months you would expect Milwaukee and Grand Haven to be warmer than Madison because of the tempering effect of the near-by water. In summer, for the same reason, you would expect the two first-named cities to be cooler. Do the figures bear this out?

Winds affect climate

These observations illustrate also an effect of the westerly-wind belt. Milwaukee and Grand Haven are both on the lake. Milwaukee, on the western shore, is colder in winter and warmer in summer than Grand Haven, on the eastern shore. Why? Since the winds are more commonly from the west, those

over Milwaukee are mostly from the land and those over Grand Haven are mostly from the lake. This you would expect, since you know that water maintains a more nearly even temperature through extremes of heat and cold. Cities on the eastern shore of a lake in the westerly-wind belt, then, will have a more even climate through winter and summer. Do the figures bear this out?

The effects of these differences are illustrated in another way by the products of the region around Grand Haven. Here you find a great peach-producing country. Peach trees cannot live through the extremes of cold on the west side of the lake.

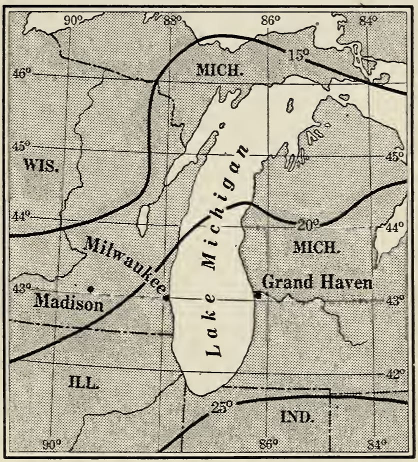


Fig. 204. Isotherms show the Average Temperatures for January. It is colder West of the Lake than East of It

You may recall from your study of winds the effects of winds and ocean currents upon climate. These effects are well illustrated in the climate along the Pacific coast. The cold of winter along the coast in the state of Washington at latitude 46 degrees is less severe than it is in southern Tennessee at latitude 35 degrees. The same effect is strikingly illustrated in the climate of eastern Europe. London is farther north than Winnipeg, in Canada. London's average temperature for January is about 39° F., and the average for Winnipeg is about – 3° F. The averages for July are for Winnipeg about 66° F. and for London about 63° F. The difference in

Differences in climates in regions of the same latitude may be due to the effects of wind and water

The map at the left shows conditions in the middle of the Paleozoic era. The map at the right shows conditions at the end of this era. Do you see any evidences of changes? How long do you think it took for these changes?

The climate of the land areas during this period was very different from what it is today. Notice the swamps which later became the Pennsylvania coal beds. Where were the Allegheny Mountains during this period? the Rocky Mountains?

Fig. 205. During the Paleozoic Era Portions of the Present North American Continent were under Water[1]

[1] Reproduced by permission from *Historical Geology*, Part II, by Schuchert and Dunbar, published by John Wiley & Sons, Inc.

the average January temperatures of these two cities is forty-two degrees and in the average July temperatures is about three degrees. The climate through the year is more nearly uniform in London. The difference between average temperatures in London for January and July is about twenty-four degrees. The difference between these two in Winnipeg is about sixty-nine degrees. In winter the temperature in Winnipeg is frequently as low as $-40°$ F. In London the temperature seldom falls below freezing.

FIG. 206. During the Mesozoic Era too Portions of the Present North American Continent were under Water[1]

What evidences can you find that the surface of the earth during the Mesozoic era had changed from that of the Paleozoic era, as shown in Fig. 205? What were the main changes? How long a period of time elapsed between these changes? Would the climate of northern Canada during this period have differed from the climate found there today? In what way? Why? Where were the Rocky Mountains during this period? the Pennsylvania coal beds?

Winnipeg is but little affected by the moderating influence of a body of water, and for this reason its climate is greatly different from the climate of western Europe. Remember, too, the influence of the Gulf Stream on western Europe. What does all this mean in relation to long-time climatic change? One con-

[1] Reproduced by permission from *Historical Geology*, Part II, by Schuchert and Dunbar, published by John Wiley & Sons, Inc.

clusion might be that climatic changes have come as the result of changes in the location of large bodies of water. Have there been such changes?

The sea once covered present coal beds

The maps in Fig. 205 show the North American continent during the Paleozoic era at the time the Pennsylvania coal beds were forming. The continent was rising and the inland sea was slowly receding, leaving vast areas of swamps. There were mountains across the northern section of what is now the United States, and there were mountains extending from east to west in the region of Colorado and Nebraska. These served as a barrier against the cold winds of the north. This, together with the fact that the inland sea was an arm of the warm ocean to the south, is perhaps sufficient to explain the tropical climate of that period.

Large inland seas which once covered part of the North American continent affected climate

There is abundance of evidence that the boundaries of the continents have changed many times through the course of the geologic eras. In the middle of the Mesozoic era, some hundred and fifty million years after the coal beds had formed, the sea was again over a large section of North America. Study Fig. 206. The mountains of the Colorado region had been worn down, and this region was now beneath the sea. The region of northern Canada must have had a warm, moist climate, for fossils of tropical plants and animals may be found as far north as the arctic circle.

It is plain that changes have occurred in the location and extent of the water area on the North American continent. It is equally plain that these changes may be used to explain some of the long-time climatic changes.

Throughout these changes you have seen another factor operating in the forces which alternately raised and lowered the continent so as to change the water area upon it. Let us consider this factor a little more at length as it affected climate.

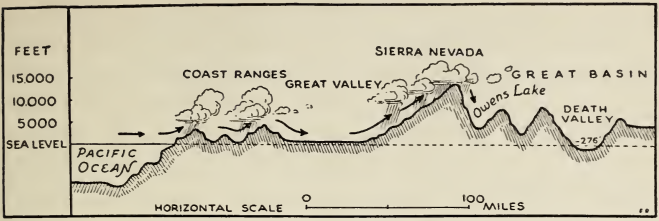


Fig. 207. Death Valley is the Result of a Combination of Many Natural Factors

Westerly winds do not bring rain to Death Valley

D. What Effects were caused by the Rising of the Rocky Mountains?

You are familiar with the effect of mountain ranges upon climate. You have seen this in southern Europe and again upon the west coast of this country and South America. Let us illustrate it perhaps a little more strikingly.

Desert regions are sometimes caused by mountain ranges

A short time ago you read about the desert country around Death Valley. You learned that it is during part of the year within the horse latitudes and part of the year within the belt of the westerlies. You know, too, that it is bounded on the west by part of the Rocky Mountain chain. These facts help you to explain why this part of the country is a desert area. The air comes over the mountains from the west. It loses moisture as it rises and cools over the western slopes. As it descends on the eastern slopes, it becomes warmer and its humidity becomes lower. As the horse latitudes shift over this area, they also bring dryness. A study of Fig. 207 may help to explain this.

As one studies the development of this desert area, one is led to the conclusion that there would be no desert here if there were no mountains. This conclusion can be supported, for fossils and sedimentary deposits indicate that at one time this region was not a desert.

Let us trace the development of the Rocky Mountains.

During the last third of the Mesozoic era, an interval of some thirty million years, the North American continent began to take on its present form. The regions of the Great Plains and of the Rockies were raised, and the water of the inland sea flowed away to the ocean. Deposits of sediments containing fossils of sea animals mark the region where the sea once was. The coal beds of the Western states mark the regions in which swamps lingered for a long time behind the receding sea. These coal beds are, as you have learned, of much more recent formation than those of Pennsylvania and Illinois.

The Rocky Mountain region was at one time under water

This elevation of land was the beginning of the Rocky Mountains, and from then on through a long period of time, probably until the present, the mountains have continued to grow. During all the time the mountains have been rising the forces of erosion have been wearing them down. At times in their history erosion has gone on more rapidly than growth, and during at least one period the mountains were worn down to nearly plain surfaces.

At the beginning of the Cenozoic, or most recent, era the mountains were in evidence but not prominent. The Gulf of Mexico extended northward to the present junction of the Mississippi and Ohio rivers. This was some sixty million years ago. In the early period of this mountain formation great rivers flowed from the mountains and left the deposits from which were formed the bad lands of the Dakotas, Wyoming, and Nebraska. As the mountains grew higher, the rainfall on the eastern slopes diminished. Today vast areas that were at one time covered by the sea, and at another time covered with dense growth from which coal beds formed, are changed to dry and nearly desert plains.

Toward the middle of the Cenozoic era the eastern coast of the continent was raised. As a result the Atlantic coast was far out from where it is now, and the Hudson River

flowed as a raging stream at the bottom of a deep gorge. Since then the land has lowered, and the deep gorge of this ancient Hudson is now the channel through which boats enter the harbor of New York City.

Do you see now why scientists believe that long-time climatic changes have taken place upon the continent of North America and that these are the result of certain other changes in the surface of the earth, extending over long periods of time? Mountains were formed, and plains were elevated. The climate became colder, and in places drier. As the land rose in some parts of the continent, it sank in others. The climates changed, and with these changes the forms of life also changed.

Mountains affect temperature and rainfall

Add to these factors the effect of the glaciers which you read about earlier in the unit, and you will see that there have been many forces operating to cause long-time climatic changes.

Perhaps as you think of the luxuriant tropical growth that flourished once in the present Mississippi Valley, Pennsylvania, and northern Canada, you may feel that the climatic changes must have been very large indeed. The facts, of course, are difficult to find, but it has been estimated that the average temperature of the continent during the interval since the glaciers has probably not changed more than 10° F. While this difference may not seem great, it has a tremendous effect upon life if it lasts for a long period of time.

Climatic changes affect the character of living things

In this discussion we have confined our attention to changes that took place on what is now the continent of North America. Similar changes have been in progress all over the world.

The main causes of changes in climate are changes in the elevation of the land and changes in the land area covered by the sea. Not nearly all the changes have been described.

There has been more than one glacial period, and there has been more than one coal-forming period.

The facts which support the explanations given here have been gathered by careful observation of rock formations. The records of climatic changes are written in the rock. These facts indicate that the glacial periods occurred when there were most high mountains and high plains and fewest shallow seas. The coal periods came when the highlands were worn down and when shallow seas covered much of the land.

Through all the period of geologic history the sun seems to have shone with about the same intensity; and although different regions have experienced great climatic changes through long periods of time, the average temperature for the whole earth has probably not changed very much through a billion years.

Climatic changes have taken place upon the earth. They have covered long periods of time. They have been due to changes in the surface of the earth. Through all the eras of geologic time the amount of energy coming from the sun seems not to have changed very much.

Can You Answer these Questions?

1. What evidence is there that gradual climatic changes have taken place over long periods of time?

2. What relationship is there between the formation of the present coal beds and changes in climate?

3. What evidence do the coal beds give that changes in climate do not occur suddenly?

4. What conclusions can you draw from the effects of glaciers as to changing climates? Are climates still changing?

5. Is there any evidence to support the conclusion that some climatic changes take place in cycles and that these cycles repeat themselves at short intervals?

6. What relationships are there between sun spots and changes in climate?

7. What evidence have you that regions near water have more even temperatures than inland regions? How are these observations explained?

8. Does the evidence of effects from land and water on climate help to explain the long-time changes in temperature?

9. What explanation is there for the conditions that cause Death Valley? Remember that Death Valley is part of the time in the horse latitudes and part of the time in the westerly-wind belt.

10. Can you trace the changes that took place during the formation of the Rocky Mountains?

11. Need the long-time changes in temperature have been very great to bring about the great changes in life which they seem to have caused?

Questions for Discussion

1. How should you find evidence to support the statement that there have been no sudden changes in climate?

2. Do you think that the angle at which the earth is inclined upon its axis might possibly change? Do you think that the Gulf Stream might possibly change? How do you think these things might happen? What effect do you think such changes might have upon life? Which of these should you think more likely to change?

3. As you think of the cold arctic and antarctic regions, do you think that coal may possibly have been formed in any other way than by decaying vegetation in some time of warm climate?

4. Suppose the Isthmus of Panama were cut through so that water could pass freely from one ocean to the other. In which direction should you expect water to flow: from west to east or from east to west? Would this affect the climate of western Europe?

5. What do you think life might be like in your part of the country if the average yearly temperature were to increase by 10° F.? if it were to decrease by this amount? Find out about conditions in regions where the average yearly temperature is ten degrees warmer than where you live; where the average is ten degrees colder.

6. Do you suppose the climate of the United States would be very different today if the mountain ranges ran east and west instead of north and south?

7. Why are there no fossils of birds or mammals in the Pennsylvania coal beds?

8. Do you know the story of the water cycle? May there possibly be a land cycle from mountains to mountains again? What do you think such a cycle might be?

9. Do you think that the coal beds of the arctic and antarctic areas may ever have any value? How widespread are these deposits, and how thick are the veins of coal?

Here are Some Things You May Want to Do

1. If you are able to get weather reports for your community over a period of the last twenty years, study them and see whether there are any evidences of climatic change. Try to get answers to these questions: Has the weather varied from year to year? Have there been yearly differences in the average temperature? in the average rainfall? Have these been very great? What other information should you look for in solving this problem? Can you make a graph to show annual change in July temperatures? in December temperatures?

2. Prepare a class report on the big trees of California. How old are they? Why do you think the government protects them?

3. Should you like to know how scientists have traced climatic changes through the rings of trees? There is an interesting story about this in the *National Geographic Magazine* for July, 1923. If you want to know more about it, ask your teacher to help you to read Huntington and Visher's *Climatic Changes.*

4. If there is a botanical garden in your city, it may have growing specimens of some of the types of plants that grew during the Carboniferous era. See what you can find out about them. Museums of natural history usually have fossils showing the outlines of these plants. Are they like any plants that grow today?

5. Look up references on the sun-spot theory. Where should you go to find such information? Just what is this sun-spot theory? If you think it interesting, prepare a report for class.

Chapter XVIII · What may we learn about the Plants and Animals that lived in the Past?

Fig. 208. What's Wrong with this Picture?

The cartoon at the top of this page is typical of many you may have seen which attempt to picture life in the far-distant past. While these cartoons differ in individual items, they usually agree in making a very common mistake, the same sort of mistake you would make in picturing Julius Cæsar throwing bombs from an airplane, in thinking of Columbus in a modern motor boat, or in showing Robin Hood in Sherwood Forest with a modern machine gun.

In these cartoons primitive man is accompanied by a dinosaur! This animal is supposed to be trained and to take the place of the modern horse. What fun, you say! Imagine a horse some eighty feet long! Imagine climbing on his back and galloping over the countryside in great long jumps! Imagine, too, the help such an animal would be to you if you were a cave man in a fight with a neighboring tribe or with some kinds of wild animals!

You know, of course, that these and similar pictures are not scientifically accurate. In the first place, so far as science can determine, the dinosaurs and primitive man did not exist at the same time. In fact, there were some sixty million years between the time the dinosaurs disappeared and the time that the first men arrived on the scene. In the second place, it is to be doubted whether the cave man looked at all like the modern man whom the artist has pictured. And in the third place, the dinosaurs usually pictured by the artists are not necessarily typical of dinosaurs as a whole. Some members of this group were as big as the one shown, but some of them were no bigger than a chicken. Some of them were carnivorous, or meat-eating; others were herbivorous, or plant-eating. Some of them did run on four legs, but others used only their two hind legs. Some lived on land, and some in water.

Some pictures of primitive life give wrong impressions

There were many kinds of dinosaurs

In other words, the artist has taken liberties with scientific fact. His ideas may be funny, but they do not present the facts. There is no reason, of course, why you should not enjoy the idea and smile at the humor the artist has tried to picture. The point is that you should not think of life in the far-distant past as it is so often represented.

But what right, you may ask, has science to question these ideas? You may argue that, since all these things happened so many millions of years ago, the artist perhaps knows as much about it as the scientist does. How does anyone know what kind of life existed in the past? How can anyone tell how long ago certain forms of life existed? These are good questions. How may they be answered?

Begin, if you will, by recalling some of the things you have learned about the formation of the surface of the earth. Remember especially how, over a long period of time, layers of sediment were deposited as the earth's crust was alternately raised above and sunk again beneath the

sea. Recall again how in time these layers of sediment were compressed until they became the rock which is recognized today as sedimentary rock. You have seen examples of this formation in the walls of the Grand Canyon and in other cliffs which have been cut away by the action of running water.

Now come down to the present day. If you have ever worked in the garden, you may have turned up many things: pieces of broken bottles, tin cans, earthworms, pieces of wood, stems of plants, perhaps the skeleton of a bird or some small animal. At the time you were digging, these things probably annoyed you, for they made your job that much harder. If you will think over your experiences, however, you will see that in this so-called rubbish you had some evidence of the life that existed in your garden a few months or years ago.

But what has this to do with the story of primitive man and the dinosaurs, you may ask? Carry your imagination a little farther and imagine that instead of digging in the topsoil of your garden you were digging or blasting much deeper into layers of soil and rock which were formed millions of years ago. Suppose that instead of finding the things like those in your garden you found remains of a different kind. Would these have any meaning to you? Would they give you any evidence of the kind of life which existed in the more distant past? It seems reasonable to suppose that they might, doesn't it?

Rocks tell the story of the past

Scientists have dug into layers of rock formed during different eras of geologic time and have thus secured certain evidence of conditions in the past. They have estimated how long ago these different layers of rock were formed. They have found certain remains of life, both plant and animal, and have been able to estimate how long ago these things lived on earth. When you understand their methods, you will probably agree that their estimates must be nearly correct.

As the result of these investigations science tells an entirely different story from that told by the artists and writers who put primitive man and the dinosaurs in the same picture. Let us follow this story for a little while.

A. What are Fossils?

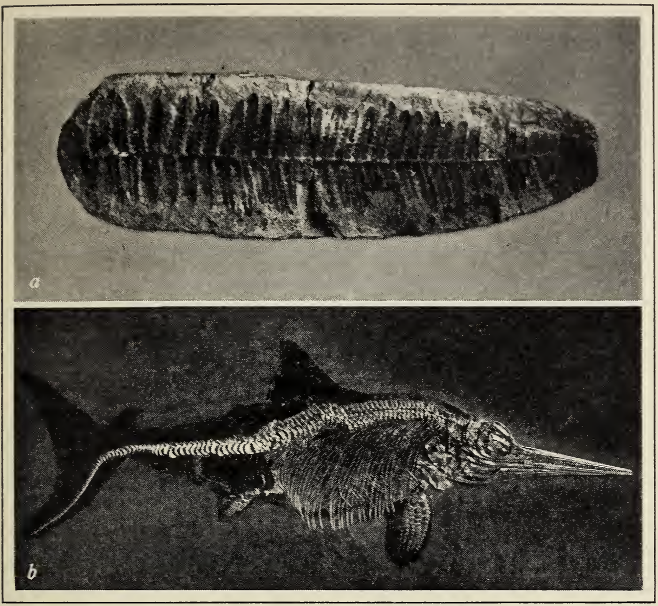
Perhaps you have seen fossils buried in solid rock. Some are illustrated in Fig. 209. From what you know about the formation of these rocks you may guess how the fossils got there. Fossils are the remains or traces of plants and animals preserved in rock. The outlines of shells, bones, leaves, and stems are fossils. So are footprints and worm casts. Any evidence of life preserved in rock is a fossil.

Any evidence of life preserved in ancient rock is a fossil

It is easy to see how fossil shells came to be set in rock. The animals lived in mud or sand along a stream or on the shore of the ocean. In the course of time the mud changed to stone. The outlines of the shells may be seen in this stone. In a similar manner the bones of animals may have been inclosed in the mud which later turned to stone. By the study of fossils we get some notion of the kinds of animals and plants that lived on the earth while the sediments in which the fossils are found were forming.

During the last few years many different kinds of fossils have been found, and knowledge of life of long ago has been greatly increased. As you see from the above, fossils are found in sedimentary rocks. A trained geologist can tell, from the way in which the layers of rock rest upon one another, which are the older layers and which are the younger. The oldest rocks are underneath the rocks of more recent formation. Obviously the fossils of plants and animals which lived longest ago are found in the oldest rocks. The

Sedimentary rocks usually contain fossils



a, Walker Museum, Chicago; *b*, A. M. N. H.

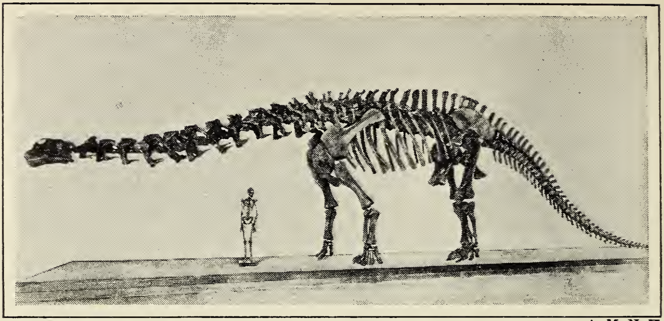
FIG. 209. **Fossils are the Remains or Traces of Plants and Animals preserved in Rock**

a, fossil remains of plant life; *b*, skeleton of prehistoric animal life

fossils of things which lived more recently are found in the rocks formed at a later date. All these fossils, however, show evidence of life upon earth in the past.

B. What Kinds of Plants and Animals lived during the Different Geologic Ages?

A short time ago, you will remember, we discussed the various geologic eras of the earth's history and described them in terms of some of the things which made them distinctive. Before you begin this section, it might be well for you to go back to this description, so that you may have it clearly in mind.



A. M. N. H.

FIG. 210. The Brontosaurus was One of the Largest of the Dinosaurs

Contrast its size with that of the man. Why could not such a dinosaur live today?

The oldest rocks were formed during the Archæozoic era. Since no fossil remains have been found in these rocks, we must decide either that there were no living things during the Archæozoic era or that all the traces of them have been destroyed during the changes that have since taken place. Geologists generally believe that there were living things during this era, but that they were of very simple form. They probably had no bones and no hard outer covering. Therefore no fossils were preserved, for the many changes in the rock since the Archæozoic era have destroyed them. Remains of life have been found in rocks formed during the Proterozoic era, but all of them have been fossils of simple forms of plants and animals. There were no fishes, no reptiles, and no mammals.

No fossils have been found in the rocks of the Archæozoic era

Life in the Proterozoic era was simpler than life in the Paleozoic era

The oldest rocks that show fossil remains of fish were formed during the early part of the Paleozoic era. Rocks formed later in the era show many kinds of fishes and the shells of various water animals. Amphibians, reptiles, and insects have also been found. The rocks formed about the middle of this era are the first to show evidence of

A. M. N. H.

FIG. 211. The Allosaurus was a Flesh-Eating Dinosaur

land animals. Previous to this time all animal forms seem to have lived in water. One of these fossils is shown in Fig. 209. Plant life was extremely abundant in this era, as is evidenced by the great coal beds of Pennsylvania and of the Mississippi Valley. Plants and animals that lived during this era were greatly different from the forms that lived during the Proterozoic era and greatly different from those that live on earth today.

The dinosaurs lived in the Mesozoic era

The Mesozoic era is called the Age of Reptiles. The dinosaurs, a kind of reptile, lived in great numbers during this era. There were many kinds of dinosaurs. Some were large, and some were small. Many dinosaurs have been reconstructed. You may see these on display in museums.

One of the largest, called the brontosaurus, weighed as much as forty tons. It was five or six times as heavy as the largest elephant that ever lived, as you can see from Fig. 210, but not so large as our largest whales. Such an animal required an enormous amount of food. The warm and moist climate which prevailed over the region of the North American continent at the time was favorable for the growth of an abundance of plants. This large dinosaur fed upon plants. The smaller allosaurus, pictured in Fig. 211,

A. M. N. H.

FIG. 212. These Fossil Eggs, laid a Long Time ago by a Dinosaur, were found in The Gobi

What geologic changes do you think have occurred in The Gobi?

was a flesh-eating dinosaur, as his teeth bear witness. The enormous but awkward brontosaurus was probably helpless when attacked by the allosaurus. Indeed, there is very good evidence that this larger animal was food for the smaller one; for their bones have been found together, with those of the larger one partly destroyed.

Some dinosaurs were carnivorous; others were herbivorous

The fossils of dinosaurs are found in many places on the earth. The members of a scientific expedition to The Gobi, a desert in Asia, found many of them. Among other things they found fossilized dinosaur eggs which are now on exhibition in the American Museum of Natural History. See Fig. 212. In North America the fossils are found abundantly in the Mesozoic rock of the region of Wyoming and Montana.

Dinosaur fossils have been found in many parts of the world

Not many years ago the fossilized bones of a dinosaur were found beneath the Palisades of the Hudson River, where they were exposed when the Mesozoic sandstone

beneath the Palisades became worn away. Here, by the way, is convincing evidence that the Palisades have been formed since the dinosaurs roamed this region, for, if they had not, the fossil could not have been beneath this great mass of igneous rock.

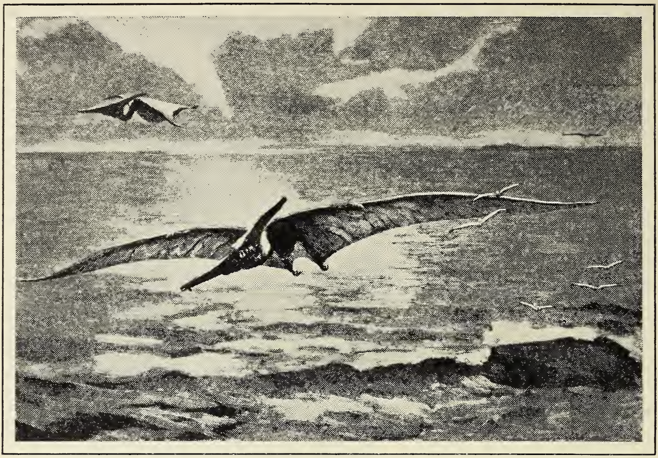
FIG. 213. Footprints of Dinosaurs are sometimes found in Stone

These were found by some science students on a field trip

There are many places in which the footprints of dinosaurs may be found in stone. These tracks were made in the mud of the Mesozoic era. When the mud hardened and became rock, the footprints were preserved. In Fig. 213 is a typical illustration of such footprints that have been found by scientists.

The age of the dinosaurs seems to have come to an end by the close of the Mesozoic era. Rocks formed since that time show no traces of them. It is believed that they lived in the warm swamps which covered much of North America during this era. As the era drew to a close, the land became elevated and the climate became drier and colder. These animals were poorly adapted to the more severe climate with its lack of abundant food, and after the change they were unable to endure. It is likely, too, that other living things came on the scene late in this era and made the eggs of the dinosaurs or even the dinosaurs themselves a part of their food. From all the evidence it is likely that several factors contributed to the extinction of these reptiles.

The dinosaurs became extinct with changes in the climate



U. S. National Museum

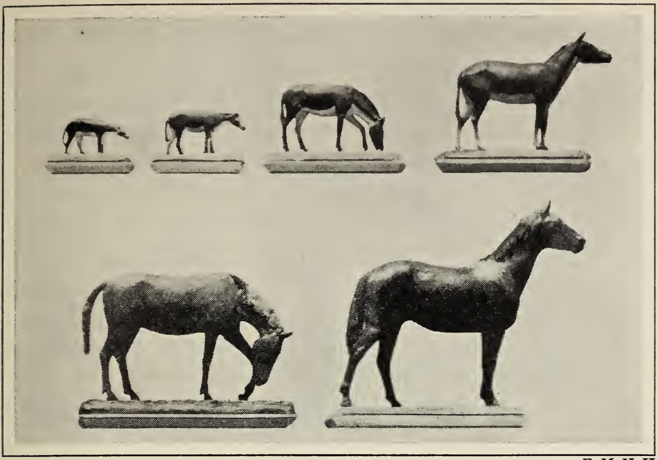
Fig. 214. The First Birds were not Unlike Flying Reptiles

The oldest fossils of birds are in the rocks of the Mesozoic era

The rocks of the Mesozoic era (which closed some sixty million years ago) show in addition to reptiles the first fossils of birds. These first birds were not unlike flying reptiles. Look at Fig. 214. They had teeth and strange paddle-like wings. The rocks of this era show fossils of small mammals also. The earth was thickly inhabited by animals and covered with dense vegetation. If you could study at first hand the environment of this time, it would seem very strange.

Reptiles marked the Mesozoic era; mammals, the Cenozoic era

In the rock of the bad lands of the Dakotas, Wyoming, Nebraska, and Colorado are found the fossils of animals that lived during the early Cenozoic era. As the distinctive animal life of the Mesozoic era is the reptiles, so the distinctive life of the Cenozoic era is the mammals. If you examined these rocks carefully, you could find fossil teeth, pieces of bone, and occasionally a fairly complete skeleton, of animals that lived some fifty million years ago.



F. M. N. H.

Fig. 215. Fossils found in the Rocks of Various Eras seem to show a Gradual Succession of Changes in the Form of the Horse

The earliest form of horse is shown in the upper left-hand corner. The horse of today is shown in the lower right-hand corner

It is obvious even to an untrained observer that the animals of this period were in some respects much like the animals of today. In many ways, however, they were quite different.

Early forms of mammals were unlike those of today

In the rocks of the early Cenozoic era are found the fossils of a small animal that bears some likeness to a horse. It was evidently much smaller than a Shetland pony, but in the shape of its head and in the proportions of the body it was like a horse. In the rocks of a later period there are fossils similar to these earlier ones. They show even greater similarity to a modern horse. The fossils collected from sediments formed through the Cenozoic era seem to show a gradual succession of changes from this earliest horselike animal of the late Mesozoic era to the familiar animal of today. This gradual change is pictured in Fig. 215.

Along with these fossils of the horse are found fossils of animals resembling cattle, hogs, dogs, cats, camels, bears, and other mammals with which we are familiar. Our age today is an age of mammals. It was during the Cenozoic era that the earth became covered with the kinds of plants and animals which we know today.

Animal life of the Cenozoic era, however, is not the only kind which has been found in fossil remains. In the mountains west of Pikes Peak, near the town of Florissant, Colorado, is another large bed of fossils. The evidence all about shows clearly how this bed was formed. Back in the early Cenozoic era this region was not mountainous. It was lowland, and the climate was warm and moist. Part of the region was covered by a lake of fresh water. Near this lake grew a forest of giant sequoias, similar to the big trees now growing in California. In the changes associated with mountain-forming, volcanoes broke out in this region. During one eruption a large amount of volcanic dust was thrown into the air. As the dust settled, it filled the lake and caused the water to overflow and surround some of the giant trees. The lake now covered a larger area, and it remained with the trees standing in it.

Petrified trees are fossils

The water was charged with soluble salts that had dissolved from the volcanic ash. Because of this change in the water level the trees were killed. They did not decay, however. The water, highly charged with mineral salts, protected the trees from oxygen. The part of the tree trunks surrounded by water petrified. In other words, their cells were replaced by minerals and thus preserved.

After a long time there was an upfolding and tipping of the land, which caused the lake to drain. A visitor to this region today may see the petrified stumps of these giant trees, as shown in Fig. 216. The height of the stumps above the ground from which they grew shows pretty closely the depth to which the water stood around them.

The tops decayed, but that part of the trees which was covered by the water from the lake when the lake overflowed was changed to stone. The animal life in the lake was killed, and it too was turned to stone. Fossils of fish, insects, reptiles, and other forms of the life of that time are found in great abundance in the rock formed from volcanic ashes on the bottom of this lake. All this region today is at an elevation of more than nine thousand feet.

Colorado Springs Chamber of Commerce

FIG. 216. A Petrified Tree Stump in the Colorado Petrified Forest near Florissant

How did this stump become petrified?

The climate of North America during the early Cenozoic times was mild and moist. The continent was inhabited by many forms of mammals. There were also insects, birds, fishes, snakes, — in fact, most of the animal forms that we know today. Conditions were favorable for life, and therefore life was abundant. You must not suppose, however, that either animals or plants of this period were the same in appearance as those that live today. As conditions upon the earth changed, life also changed.

The early Cenozoic era was rich with life

The late part of the Cenozoic era is called the Glacial Age. During this period glaciers covered a large part of northern North America and northern Europe. The Glacial Age, however, was not a continuous period of cold. At times it was warmer, and the glaciers receded. During a period of perhaps a million years the ice advanced and receded as many as four times.

There was more than one glacial period

The three intervals between these advances are called interglacial periods. During the interglacial periods animals moved northward, and plants grew where the ice had been. Each time the ice advanced, the animals were again driven southward. The last of the glaciers began to recede only about thirty thousand years ago. The plant life and the animal life now on the region once covered by glaciers have spread over this land since that time.

From this story you can perhaps begin to understand how scientists have estimated the length of life on the earth and how they have been able to describe the particular kinds of life that existed long ago. The records in the rocks show the character of the plant and animal forms that have lived on earth through many millions of years. The earliest forms show little similarity to those of today. Throughout these eras the forms of life were continuously changing, and life as we know it today must have developed from these earlier forms.

The forms of life changed through the various eras

C. What do the Rocks tell about the Early Ancestors of Man?

You have now read some brief descriptions of living things preserved in the mud probably three fourths of a billion years ago. You have seen some evidence that the dinosaurs lived in the swamps and river valleys more than a hundred million years ago and that, at a later time, small and peculiarly shaped horses, camels, and other mammals appeared upon the scene. In the American Museum of Natural History are collected more than twenty thousand fossil mammals which have been brought in from various parts of the world. Other museums contain similar collections. The stories you have read, then, are not based on occasional finds but upon many records in many rocks taken from many parts of the world.

But what about man? Are his bones found among those of the other animals? If so, how old are the deposits in which they are found?

There is nothing in the rocks formed during the first four of the geologic eras to suggest the presence of man on earth. In fact, it is not until one comes to the rocks formed during the last part of the Cenozoic era that fossils of man are found. The oldest remains resembling man are probably about a million years old. Compared to the age of the earth, the age of man is extremely short. The rocks at the bottom of the Grand Canyon, for example, are more than one thousand times older than the oldest traces of human beings.

The rocks of the first four geologic eras show no evidence of man

Some roughly chipped stones have been found in the rocks formed soon after the middle of the Cenozoic era, but the oldest traces of bones resembling those of human beings date from a much later time. The Java man (fossils found on the island of Java) and the Peking skeletons (found near Peiping (Peking), China) are the remains of beings that lived about a million years ago, before the glacial period. The Heidelberg man (found near Heidelberg, Germany) lived several hundred thousand years later, during the second interglacial period. It is evident from these finds that early men, like early horses, were quite unlike those that live today. Look at Fig. 217.

The oldest human remains are found only in sediments of late Cenozoic era

Of still later date (the third interglacial period) is the Piltdown man, found in the gravel of an old river bed near Piltdown, in Sussex, England. The story of this find is interesting. Some twenty years ago a group of laborers getting gravel to make a roadbed dug out a skull, a lower jaw, and a few other pieces of bones. Even to the laborers these bones suggested manlike features, but appeared unlike those of modern men. Scientists were called to the scene to view the find. The gravel deposit was compared

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Fig. 217. Early Men were quite Unlike those that live Today

The casts at the top were modeled from a study of the skulls below. Since not all parts of some skulls have been found, the missing parts have been restored in white plaster. The men represented are (*a*) Java, (*b*) Piltdown, (*c*) Neanderthal, (*d*) Cro-Magnon

with others, and its age was determined as somewhere in the neighborhood of a hundred and fifty thousand years. It was obviously the bed of an old river, and the bones had evidently been washed downstream and buried there. The bones, then, were older than the gravel deposit. The skull, partly fossilized, was smaller and flatter than that of a modern European, showing that the front part of the brain was less developed. There was no question that it was a human skull, however. The jawbone found near the skull seemed less like a human bone. The canine tooth was

The Piltdown man is an early form of human life

Modeled by Frederick Blaschke, © F. M. N. H.

Fig. 218. The First Neanderthal Man lived in the Third Interglacial Period

What evidences are there that these are likenesses of men who lived so long ago?

extremely long and pointed, unlike those of any modern man, and the jaw was chinless. Some authorities believed that the jaw did not belong with the skull at all, but belonged to another animal. But shortly afterwards, about two miles away, a second skull was found and with it a tooth like the long one in the other jaw. The finding of the skull and the jawbone together might have been chance in the first instance, but the same thing would hardly happen twice. After careful study, authorities agreed that the Piltdown man who lived in England more than a hundred and fifty thousand years ago had a fairly well-developed brain, but that in certain other respects, especially in the shape of the jaw, he was very unlike modern man.

A. M. N. H.

Fig. 219. The Stone Implements used by Early Men were extremely Rough

The Java, Peking, Heidelberg, and Piltdown skeletons are not the only representatives of these older races. The first bones of Neanderthal man, also of the third interglacial period, were found in a cave near Neanderthal, Germany. Since then many other specimens similar to those found near Neanderthal have been found in caves in Belgium and in France. In Fig. 218 is represented a scientist's idea of the Neanderthal man. It should not be thought that the Neanderthals were of a high type of civilization, for they most certainly were not.

The Neanderthal man represents an important early race

The stone implements used by these men were extremely rough. They were made of flint and quartzite and were chipped to a size and shape that could be held in the hand. Look at Fig. 219. There was no polishing of sharp edges, such as was true of stone implements of a later day. In order to distinguish these rough instruments from the later ones, the early ones are spoken of as be-

The period of these early races is called the Stone Age, for they used only stone implements

longing to the Paleolithic, or Old Stone, Age. The later ones, more skillfully made and well finished, belong to the Neolithic Age. *Neolithic* means "new stone." The Neolithic Age came late in the development of man.

Neanderthal man belongs to the period of time that came just before the beginning of the fourth and last glacial period. Numerous skeletons of Neanderthal man are found in caves and in rock shelters. These are associated with rude implements and with the bones of animals such as the mammoth, the saber-toothed tiger, the reindeer, and the woolly rhinoceros. They are unlike modern man in many respects, but more like him than are any of the earlier forms. Because there are so many remains of the Neanderthals and because they are distributed so widely, we have been able to learn something of their lives.

Neanderthal man was a hunter

Neanderthal man walked with shoulders slightly slouched forward and with knees bent. His hands were large and his arms long. How do we know? The shape and the size of his bones tell the story. The weapons that he left and the bones of animals associated with his own show that he was a hunter and roamed over the land in search of reindeer and mammoths, from which he obtained meat for food and furs for clothing. His Europe was a cold country, and he needed good warm skins. He lived within the shelter of caves, but not far inside because of their continuous dampness and darkness. He was really a "rock-shelter" man rather than a "cave" man.

Then came a period when the climate of Europe was extremely cold. The glaciers of the fourth and last great advance spread over Europe. The glaciers came slowly, just a few inches each year. They crept down from the north and down the sides of mountains. Each succeeding generation of men had a harder and harder time, and they must have moved farther and farther south to escape the severity of the cold.

Shortly after the end of the glacial period, there ap-

Modeled by Frederick Blaschke, © F. M. N. H.

FIG. 220. Cro-Magnon Man seems to have been a Capable Artist

This photograph of a museum group shows a Cro-Magnon man drawing pictures on the walls of his cave

peared upon the scene another race of men. These men were not descendants of the Neanderthals. They apparently came either from Asia or from Africa. They are known as Cro-Magnons (named from the cave where one of the first skeletons was found). The Cro-Magnons gradually replaced the remaining Neanderthals, as the white men have within a few generations replaced the Indians in America.

The Neanderthals were followed by the Cro-Magnons

These Cro-Magnons were much more advanced than the Neanderthals. Their skulls show that they had large brains with high foreheads and well-developed speech centers. Their hands show that they were well able to make and use tools. The shape of their leg bones proves that they walked erect. They were taller than many modern Europeans. Their ancestors had without doubt lived for many generations in Asia or Africa before coming to Europe, but as yet no one knows enough of the records of

A. M. N. H.

Fig. 221. Some of the Pictures drawn by Cro-Magnon Man are remarkably Good

This photograph shows a drawing found on the wall of a cave once occupied by the Cro-Magnons

man in those other lands to be able to say much about their history. Perhaps we shall know all of it some day.

The Cro-Magnons lived in groups

These men used stone implements which were carefully and accurately made. The Cro-Magnons were intermediate between the Paleolithic and Neolithic ages. They painted pictures. They carved images from the tusks and horns of animals. They made pottery and decorated it. They made little clay gods and goddesses. They lived in the open, although usually near caves along a river bank. They lived in groups and worked and hunted together.

Cro-Magnon man was always a hunter. He had no domestic animals and raised no food crops. As a consequence his home was not permanent, for he had to go where food was abundant. He was a capable artist, but seems to have had no written language. In Fig. 220 is an artist's idea of the Cro-Magnon man in his cave. In Fig. 221 is a photograph of existing cave drawings. The Cro-Magnon man was the first to show in a marked degree the physical and mental traits of man as we know him today.

D. What Evidence have we to prove the Gradual Progress of Civilization?

One must not think that the Cro-Magnons continued and that the present races of Europe descended from them. The evidence seems to show that these people disappeared, too, and that some ten thousand or twelve thousand years ago other races possessing a higher level of culture lived in Europe. They lived in villages, domesticated animals, practiced religious ceremonies, made jars from clay, and worked in bronze. This was a great advance over the civilization of earlier inhabitants, who were limited to work with wood, stone, and bone.

Increasingly civilized races followed the Cro-Magnons

The earliest evidences of this advanced culture are found in western Asia and northern Africa. It seems likely that these people, who took the place of the Cro-Magnons in Europe, had their origins in one of these regions. During an interval covering a few thousand years just before the dawn of recorded history they seem to have spread to all parts of the world. This conclusion is suggested by the fact that the cultures of all people today have much in common. They seem to have spread into eastern Asia and were the ancestors of the Chinese, the Japanese, and the Eskimos. Apparently they crossed the Bering Strait from Asia to America and became the American Indians. They moved northward into Europe and developed into the Europeans of today.

A new race spread to all parts of the world

Although modern races of men are almost certainly not direct descendants of the Cro-Magnon, any more than the Cro-Magnon was a descendant of the Neanderthal, they do seem to have had their origins in almost the same geographical region. One did not descend from the other, but both had their origin in a common ancestral race.

Modern man has not descended from the Cro-Magnons

The first civilizations to leave a written record existed about six thousand years ago. These first records show that the early civilizations possessed a high stage of culture. Without doubt many of the qualities of civilization had developed before the era of written records, and people had learned to live together to their common advantage. They built homes, cultivated the soil, engaged in commerce, and developed a form of government.

Written records are only about six thousand years old

The sweep of developing civilization from the time of the Old Stone Age, as represented by the Heidelberg, Neanderthal, and Cro-Magnon men, is too long a story to tell at length here. A great many books have been written about it. You can probably find some of these in your own school library. Examples of steadily increasing culture may be found as you progress in your study from the earliest records of man to the present.

Following the Stone Age came other periods in the development of the life of man. Copper and then bronze became the base of various types of civilization. Finally the use of iron was discovered. It was a great advance when man learned to polish rough stones, but many thousands of years passed after this before he learned to take iron from ore and make it into tools and machinery.

The Stone Age was followed by the Copper, Bronze, and Iron ages

Throughout all these periods man's culture increased. Evidence has been found of peoples who lived in the region that is now Switzerland. They built homes upon platforms which extended out into the waters of convenient lakes, as illustrated in Fig. 222. Structures similar to these are built in some East Indian islands today. On the shores of these lakes have been found the remains of agricultural civilizations.

Over four thousand years ago the Assyrians and the Egyptians had developed high types of civilization. The civilizations of Greece and Rome are over two thousand

A. M. N. H.

Fig. 222. A Race of People who once lived in the Region now Switzerland built Homes upon Platforms which extended out into the Waters of Convenient Lakes

This is a picture of a museum model showing the homes of the lake-dwellers

years old. The earliest American civilizations have their origin in races that probably came into America from Asia. Recent discoveries show that civilizations of rather high order were developed in many places on the American continents.

You may be curious to know a little more about the origin of the American Indians. They belonged to the New Stone Age, because except in a very few cases they had no implements and no weapons other than those made of stone.

The Mayans belonged to the Stone Age

The best authorities at present believe that probably somewhere in the neighborhood of twelve thousand and not more than thirty thousand years ago the first "Indians" crossed from northeastern Asia into Alaska and spread southward through North and South America. There may have been many migrations, as was the case in Europe. These early Americans were certainly not in communication with people of other continents. Therefore it is logical to believe that civilizations like the Aztec, Mayan, and Indian grew up in America independent of outside influence.

From this brief sketch of the development of civilization you see that the history of man on earth is a history of progress from a time when he could do nothing more than fashion pieces of stone into rude implements to the times of today, when men ride in automobiles and airplanes, talk over the radio, build skyscrapers, answer in scientific terms many of the questions concerning the nature of things, and express their feelings in works of art or other types of creative effort.

Man's history is one of gradual progress

As one studies this story of man, it is interesting to consider what may happen within the next thousand or even hundred years. Will man's ways of living be improved? Will man's happiness increase? Who knows? Perhaps a more practical question to ask is "What will happen during your lifetime, and how may you contribute to the work of raising the human race to ever higher levels of conduct and happiness?"

Evidence from records found in the earth shows that progress in the development of living things has been from simple to more complex forms. Human life is among the most recent of all, and in terms of geologic time the period of man's existence is very short. Man's history shows his gradual and continuous progress.

Can You Answer these Questions?

1. What evidence is there that primitive man and the dinosaurs did not live at the same time?

2. What are fossils? How do rock formations help to determine the age of the fossils?

3. Why are fossils found in sedimentary rocks and not in igneous rocks?

4. Is there evidence that there were living things on earth during the Archæozoic era?

5. Is there evidence that there were living things on earth during the Proterozoic era?

6. What forms of life were there during the Paleozoic era?

7. Why is the Mesozoic era called the Age of Reptiles?

8. Can you suggest some possible reasons why there are no dinosaurs today?

9. What is petrified wood?

10. How old are the oldest remains of man?

11. What differences are there between these early men and man today?

12. This chapter mentions several types of early man. Among them are the Piltdown, the Neanderthal, and the Cro-Magnon man. What were some of the distinctive traits of each of these?

13. Where is it believed that the modern races of man had their origin?

14. What evidence does this chapter give you of the steady progress of civilization?

Questions for Discussion

1. Scientists say that the dinosaurs were reptiles and not mammals. Why?

2. Do you think that dinosaurs could live in any part of the world today?

3. Did dinosaurs live in all parts of the world? What explanation is there for your answer?

4. How do you think the life of ancient man, such as the Piltdown, the Neanderthal, or the Cro-Magnon man, differed from life today?

5. A statement has been made that "the cultures of all people today have much in common." What do you think is meant by this? Do you have any evidence to support it?

6. Are there any races of people living in the world today who are not much farther advanced than some of the types of early man?

Here are Some Things You May Want to Do

1. For a good account of how scientists have found out about the ancient Mayan civilization read Morris's *Digging in Yucatan.* This tells you something about Chichen Itza, or the City of the Sacred Well. If you want a really exciting adventure story of ancient civilizations, read Janvier's *The Aztec Treasure House.* As you read it, however, remember that it is only fiction.

2. One of the best books on early man is Osborn's *Men of the Old Stone Age.* It has good pictures illustrating the work of scientists in unfolding the story of primitive man. It has many pictures showing the life of these early people.

3. Two of the dinosaurs named in this chapter are the brontosaurus and the allosaurus. There were many others, including the tyrannosaurus, the triceratops, the diplodocus, and the stegosaurus. These are difficult names, aren't they? Why do you think the animals were so named? See if you can find out.

4. Here are some stories that you may like to write. Be sure that your facts are correct as far as you can make them so.

The Life Story of a Dinosaur
A Boy in the Old Stone Age

5. Roy Chapman Andrews is one of the modern fossil-hunters. See if you can find any of his stories. One place to find them is in the *National Geographic Magazine.*

6. Do you think there were any differences between the kinds of fishes and other water animals that lived during the Paleozoic era and those living today? What differences do you think there might have been? Where should you go to find out?

7. What evidence can you give to show that the life of modern man shows progress over that of primitive man? Prepare a report on this for your class. Let your report show evidence in dress, tools, weapons, houses, art, literature, and the like.

8. Some scientists believe that at one time continents now separated by water were connected by land, as South America and North America are today. They believe that there have been land areas connecting Africa and Europe, North America and Europe, North America and Asia, and Asia and Australia. What evidence do they find to support these beliefs?

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Fig. 223. Powerful Forces raise Mountains, and Other Forces wear them Down

UNIT V

Where does the Energy of the World Come From?

Chapter XIX · What is the Origin of the Forces that change the Surface of the Earth?

Chapter XX · What are Some of the Characteristics of Radiant Energy?

IN YOUR study of the changing environment, you have learned of the rotating and revolving planets, of stars moving through space, of winds and ocean currents on the surface of the earth, of the elevating and wearing down of mountains, and of the activities of living things. Everything is changing. Nothing seems to be fixed or permanent. Why? What is the origin of the forces that produce change? The answer is *energy*. Forces are required to cause change, and these forces come from energy.

You may say that a thing has energy if it has the capacity to do work. You know there is energy in the wind, for you have seen it carry dust and sand. There is energy in falling water, for you have seen that it wears down mountains. The planets possess energy, for they revolve and rotate. Living things have energy, for there is activity in all living cells.

What is the source of energy? You have learned that heat from the sun's rays causes winds and ocean currents, and causes water to evaporate from the earth's surface. The energy of living things comes from the sun. Solar energy may be changed to other forms of energy on the surface of the earth. It may be changed to heat, which is the energy of moving molecules. It may be changed to electricity, which may be thought of as the energy of moving electrons. Man gets energy needed to run machinery from sources which have their origin in the sun's rays.

Another source of energy is in the molecules of substances that compose the hot rock beneath the surface of the earth. Forces from this source push up mountains and break out from volcanoes with explosive violence.

Forces with their origin in the sun's rays and in the hot rock within the earth may raise objects against the force of gravity. You will learn in this unit that energy from the sun and from the molecules of substances within the earth, together with the force of gravitation, cause the changing environment. As long as the sun shines these changes will continue.

Chapter XIX · What is the Origin of Forces that change the Surface of the Earth?

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Fig. 224. Niagara Falls are the Result of Powerful Forces

You have learned of the powerful forces working within and upon the earth. You see evidence of these forces when you look into the mass of boiling hot lava in an active volcano, when you see the effects of a strong wind or when you watch a stream of water rushing down a mountain side. Even such a magnificent spectacle as Niagara Falls (Fig. 224) is the result of such forces. You may see in these phenomena evidence of the forces that build up mountains and of the forces that wear them down.

In this chapter it is necessary to use the terms *force* and *energy*. It is difficult to form in simple language scientific definitions for these terms, but many observations associated with force and energy may be described. You may

think of a force simply as a push or a pull. Running water exerts a force, for the water pushes rocks along in its course. The wind exerts a force, for the force of the wind may push houses down. A thing has *energy* if it has the capacity to exert a push or pull. The push or pull is an effect. Energy is the source in which the push or pull has its origin. There is energy in running water; it does exert a push. There is energy in solar radiation; powerful forces have their origins in it.

A. What is the Character of the Force that forms Volcanoes and What is its Origin?

It is not easy to comprehend the vastness of the force that sometimes breaks loose in a volcanic eruption. The most violent volcanic explosion of which there is any record was the eruption of Krakatoa, a volcano in the East Indian islands, near the island of Java. This eruption occurred more than fifty years ago. During a period of three days some thirteen cubic miles of rock and one cubic mile of fine dust were hurled into the air. No force under the control of man is nearly so powerful as the one that was here in action.

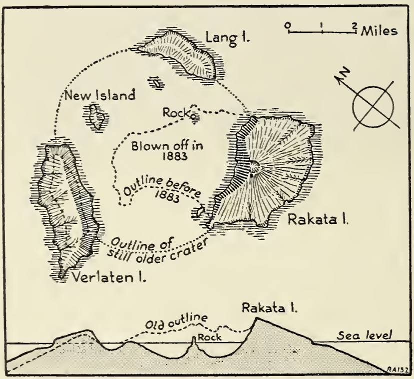

FIG. 225. Powerful Forces may be observed in the Results of a Volcanic Explosion

It is quite possible that at one time the islands of this group around Krakatoa were parts of one large island

Some comprehension of the strength of volcanic force may be had from a few comparisons. One cubic foot of earth weighs one hundred fifty pounds. This is as much

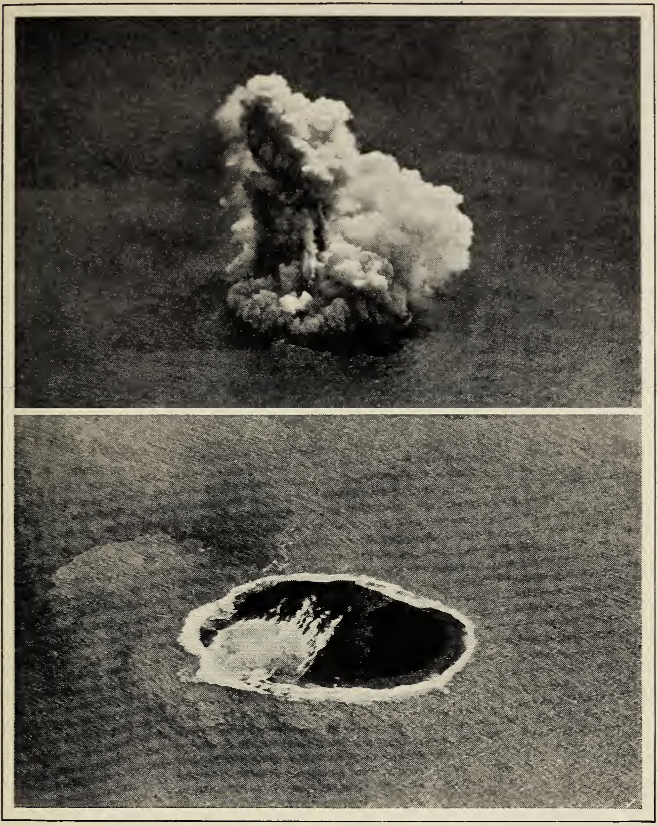

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FIG. 226. Some Regions of the Earth are still Regions of Great Volcanic Activity

This volcanic island is located near Krakatoa. Notice the boiling water around the edge of the island

as a strong man can lift. The largest steam shovel will raise one cubic yard of earth. Two cubic yards is a load for a powerful truck. One cubic mile is nearly six billion cubic yards. A line of trucks long enough to extend twice around the earth would be required to haul one cubic mile

of earth; yet Krakatoa hurled fourteen cubic miles of earth into the air during one eruption. The map and profile in Fig. 225 show some of the results of this eruption. This region of the earth is still one of volcanic activity. The pictures in Fig. 226 were taken near Krakatoa from an airplane a few years ago.

Powerful forces are in evidence in a volcanic eruption

Observations of volcanoes and of other phenomena furnish clear evidence that beneath its surface the earth is very hot. This heat is the energy of the molecules of matter of which the rocks are composed. The molecules are in motion. The higher the temperature the faster they move. The energy of molecular motion causes pressure. This pressure, equal in all directions, is the force that causes a volcanic eruption.

B. What is the Force that pulls Objects to the Earth?

"All that goes up must come down" is an old statement that describes a most familiar observation. All matter — solids, liquids, and gases — is pulled toward the center of the earth by the force of gravity. This force pulling on objects makes them heavy. The pull of gravity on one cubic foot of earth is, as you have just learned, a force of about 150 pounds; the pull of gravity on one cubic mile of earth is a force measured in billions of tons.

You may now recognize two forces, each of which has its origin from within the earth. One is the force of the moving molecules of matter composing the hot rocks beneath the surface. This force acts as a pressure against the solid crust which covers it. The other force is gravity. These are in a sense opposing forces. The moving molecules exert pressure away from the center of the earth. Gravity is a pull toward the center of the earth. Ordinarily we may think of these two forces as balanced one against the

The force of moving molecules opposes the force of gravity

other. The molecular force from within the hot rocks is restrained by the weight of the earth's crust above. But the earth's surface is always changing. There are changes which disturb the balance between these two forces. There are other changes that restore this balance. In extreme cases these forces may cause volcanic eruptions or cause the crust of the earth to rise and fold into mountain ranges.

C. What is the Origin of the Forces in the Wind and in Running Water?

If you answered the question above by saying the sun, you would be answering correctly, for you have seen that the energy from the sun causes the winds to blow, and water to evaporate and at a later time to fall as rain.

We should like you to go a little farther, however, and learn the origin of these forces. We should like you to understand how the energy of the sun is changed into the energy of wind and running water. A thorough knowledge of this change involves an understanding of some of the theories which science has developed over many years of work and study. Suppose we trace this story for you.

Let us begin by recalling that there is energy in the sun's rays, and that powerful forces have their origin there. The energy of solar radiation passes through ninety-three million miles of space in its journey from the sun to the earth. On the earth a large part of the energy of solar radiation is changed to heat energy. This, as you may already know, is the energy of moving molecules.

This heat energy from solar radiation makes the wind blow. How? you may ask. Part of the answer has been told in a previous chapter on winds. But let us look at the problem a little more closely. The earth is not heated evenly over all its surface. Solar radiation is most intense at or near the equator and least intense at or near the poles. Heat is distributed over the surface of the earth by the

movement of the atmosphere. What has this to do with wind? In order to answer this question you must recognize the force of gravity and the force of moving molecules in the gases that compose the air. You may see in the work of the wind evidence of these two forces working at the same time.

The force of gravity pulls air toward the earth, for air has weight. The molecules composing it are continually in motion and consequently exert pressure in every direction. Air pressure at the surface of the earth is normally about fifteen pounds per square inch. The molecules are pressing toward the surface of the earth with this much force, but they are pressing away from the surface with the same force. This pressure, as you know, will support a column of mercury in a barometer to a height of about thirty inches. The more heat energy the molecules possess, the faster they move, and the greater the pressure they exert. The force of gravity, however, remains the same at a given place all the time. Thus you see that the balance between the forces represented by the downward pull of gravity on air and by the upward force of molecules in motion is continually disturbed by the energy of solar radiation. This disturbance makes the wind blow.

Gravity and solar energy make the winds blow

At the equator, where heat energy is most intense, the molecules of the gases in the air are moving faster than the molecules of gases at the poles, where heat energy is least intense. The molecules moving more rapidly over the equatorial regions collide with each other more frequently and consequently exert greater pressure outward. More rapid movement forces the molecules farther apart. Warm air is therefore less dense than cold air, and a cubic foot of it weighs less. In other words, the attraction of the earth upon a cubic foot of cold air at the surface is greater than the attraction upon an equal volume of warm air.

A cubic foot of cold air weighs more than a cubic foot of warm air

Since the force of gravity is very nearly the same all over the earth, the cold air of the polar regions is attracted with more force than is the warm air of the equatorial regions. The colder and denser air moves along over the surface of the earth. This causes the warmer and less dense air to rise. But the cold air is warmed as it spreads southward, and the warm air is cooled as it moves upward. The colder air lessens in density as it is warmed, and the warmer air increases in density as it is cooled. Thus you see that the force of moving molecules, having its origin in solar radiation, and the force of gravity, having its origin within the earth, working together, cause the wind to blow.

The wind often moves with sufficient force to carry sand and soil. A wind blowing thirty miles per hour may carry sand grains as large as the head of a pin. A stronger wind carries even larger particles. When these strike against rock, the effect on the rock is like that of moving sandpaper. A continual bombardment of sand grains moving with a speed of thirty miles or more per hour is very destructive not only of rock but of everything else in its path. Since most sand is blown along near the ground, it frequently happens that telephone poles set in sandy country are cut off by the continual grinding action of the sand. Rocks are cut in the same way. A rock eroded by wind-blown sand was shown in Fig. 173.

Thousands of tons of sand and soil may be transported from one place to another by the wind. This force that wears down rocks and carries soil particles from one place to another has its origin in the action upon each other of the force of gravity and forces set up by solar radiation.

How about the force of running water? This, too, has its origin in the same sources as the wind. Heat energy from solar radiation causes water to evaporate, that is, to change from a liquid to a gaseous form. The energy thus acquired by molecules of water causes them to rise from a liquid surface against the force of gravity. They are

carried over the land by the wind. In the air they lose some of their heat energy, that is, the air gets cooler. When there is sufficient loss of energy, the molecules move so slowly that they come together and form drops of water. The force of gravity pulls these drops back to earth. On the earth the force of gravity causes the water to flow downhill toward the sea.

The energy within molecules causes them to rise against the force of gravity

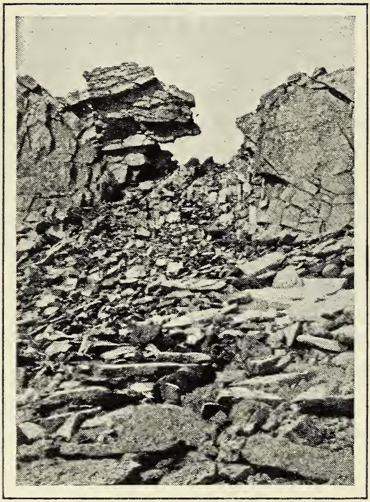


Fig. 227. Mountains are worn away by Forces having their Origin in Solar Radiation and Gravity

This scene is near the top of Long's Peak in Colorado

The amount of water that enters the air by evaporation in one year is enough to cover the entire surface of the earth to a depth of nearly three feet. Water three feet deep over one square mile weighs about 2,500,000 tons. The area of the earth is about 200,000,000 square miles. The total amount of water, therefore, that falls as rain over all the earth is about 500,000,000,000,000 tons a year.

Energy that comes from the sun furnishes the force that causes this great quantity of water to rise against the force of gravity. About 30 per cent, or about 150,000,000,000,000 tons of water, falls upon the land in one year. The remainder falls upon the surface of the oceans. The force of running water, then, is a force of some 150,000,000,000,000 tons of matter moving from the land toward the sea. As it moves it carries along particles of soil and rock. The force

of gravity and force from the energy of the sun have kept the water flowing as a continuous cycle throughout the millions of years of geologic time.

The force that causes rocks to expand when heated is a molecular force that has its origin in solar radiation. The force of expansion which is exerted by water when it freezes in crevices is also molecular. These forces and some others break rock into small pieces and convert some of the matter of which rocks are composed into soluble form. These forces, together with the forces of the wind and running water, gradually wear away the solid rock and move the pieces from higher to lower levels. Working slowly but continuously they finally wear away the highest and the hardest mountains. Look at Fig. 227. All high mountains — the Himalayas, the Alps, the Rockies, and the Andes, are young mountains, formed during the most recent of the geologic eras (Cenozoic). There is evidence, as you have learned, that mountain ranges have been formed in other places and worn down nearly to sea level. The action upon each other of gravitational force and the forces having their origin in solar radiation is responsible.

Mountains are worn away by forces having their origin in solar radiation and gravity

D. How does the Wearing Down of Mountains affect the Balance of Pressure between the Crust of the Earth and the Hot Rock Beneath?

At the present time the crust of the earth seems pretty steady or firmly fixed over most of the United States. There is but one active volcano, and in this one the activity is feeble. Severe earthquakes are not common. The Rockies may still be rising, but the process is extremely slow. We may suppose, therefore, that the pressure from the crust of the earth on the hot rock beneath is nearly equal over this entire region. But the surface of the earth is continually

changing. The high mountains are being worn down and moved away. After mountains are worn down there is obviously less pressure on the hot rock beneath than there was before. The materials of which the mountains were composed have been spread over other regions. There the pressure has been increased. Adjustments for these changing pressures must be taking place within the earth continually. These changes are too complex for us to analyze at this point, but it is easy to see that regions may be raised where pressure from the surface is least, and that regions may be lowered where pressure from the surface is greatest. Perhaps Fig. 193 helped to explain this. The action upon each other of the force of gravity, forces associated with molecular motion in the hot rock beneath the crust of the earth, and forces with their origin in solar radiation causes the earth to tremble with earthquakes, volcanoes to explode, and mountains to rise and be worn away again.

E. What is the Source of the Energy that is stored in Growing Plants?

You have already learned that sunlight is necessary for the growth of green plants. The tissues of a plant are composed of chemical elements from the air and the soil. By far the largest amount of dry plant tissue is composed of carbon, hydrogen, and oxygen. These elements are derived from carbon dioxide (CO_2) in the air and from water (H_2O) in the soil. The products formed in largest amounts by the chemical changes that take place in green plants are sugar, starch, and cellulose.

There is no usable chemical energy in carbon dioxide or water alone. But chemical changes take place when these simple substances are made into food. During these changes energy from solar radiation is stored. If it could all be released at once, the energy in a pound of sugar would exert force enough to raise a load of five hundred tons of sand

or coal a distance of five feet against the force of gravity. There is almost as much energy in a pound of wheat. An enormous amount of solar energy is stored in growing plants. An acre of wheat will produce about twenty-five bushels of grain, and each bushel weighs sixty pounds.

The energy of growing plants comes from solar radiation

All plant products have energy in them. When these products are used for food by animals, the energy is released for the vital processes that go on within the animal. You know that there is energy in wood, dry leaves, and grass, for when these are burned, heat energy is released.

All over the earth green leaves are exposed to sunlight. Chemical changes go on in every leaf, and energy from the sun is stored in plant tissue. When the growing season is over, however, the leaves fall, and the plants die. Now the products of growth go through the process of decay, and the energy which has been stored is released slowly. Perhaps the plants are burned, and the energy is released rapidly by the burning process.

The effects of gravity and of solar radiation are among our most familiar phenomena, and we are frequently reminded of the force that lies within the hot molecules that compose the rock beneath the crust of the earth. Forces with their origin in solar radiation and in the hot rock beneath the earth's crust tend to move objects in a direction away from the center of the earth. The force of gravity tends to pull them toward the center of the earth. The combined action of these forces causes the changes that take place on the earth's surface.

The surface of the earth is continually being changed by the combined action of the force of gravity, forces associated with molecules in the hot rock beneath the crust of the earth, and forces with their origin in solar radiation.

Can You Answer these Questions?

1. Can you give a simple definition of force?

2. Can you give a simple definition of energy?

3. Can you explain how a volcanic eruption is caused by the energy of molecules?

4. Can you explain wind in terms of the molecular theory and gravity?

5. Can you explain how the force of running water has its origin in the sun's rays?

6. How does the wearing down of mountains affect the balance of pressure between the crust of the earth and the hot rock beneath?

7. What is the process by which energy from the sun is stored in growing plants?

Questions for Discussion

1. What do you think would happen to life on earth if the force of gravity were less than it is?

2. Why is it that in spite of all the rivers of the world pouring water into the oceans, these large bodies of water keep at about the same level?

Here are Some Things You May Want to Do

1. Have you ever read about violent sand storms in the desert? See what you can find out about them, and report to class.

2. A famous volcanic eruption of recent date took place in Alaska when Katmai became active. The *National Geographic Magazine* has stories about this. It is the region known as the Valley of Ten Thousand Smokes. Read about it, and report to class.

3. Make a collection of pictures showing how the wind changes the surface of the earth. Include some pictures of sand dunes and sand storms.

4. Examine a small stream bed after a heavy rain and make a report telling how running water changes the surface of the earth. Perhaps you would like to photograph what you find.

Chapter XX · What are Some of the Characteristics of Radiant Energy?

At the present time no one can say what radiant energy really is. Yet, along with gravity, it is one of our most familiar phenomena. You know something of radio waves and of infra-red rays. You know more about light waves. You have heard of ultra-violet rays, X rays, and cosmic rays. All of these are forms of radiant energy. These are all alike in the speed with which they travel through space. They all travel as waves, although they differ from each other in wave length. Radio waves are longest and cosmic rays are shortest. The others are distributed in order between these extremes. Since the wave lengths (and frequencies) are different, the effects which they produce are different.

Radiant energy occurs in many forms

Solar radiation, the energy that comes from the sun as rays, is one form of radiant energy. Within the range of solar radiation are the waves of light by means of which we see. There are also the invisible infra-red and ultra-violet rays. The energy that comes from the sun makes vision possible. It also makes green plants grow. You have already learned that it causes the winds to blow and water to be distributed over the earth. It heats the rocks and causes them to expand and break.

Solar radiation is one form of radiant energy

Light is the most familiar form of radiant energy. In your study of the sun and of other astronomical bodies you have learned something about the velocity, or speed, of light. You have also learned something about the messages which it carries from the sun, the planets, and distant stars. Although no one can say what light really is, a great deal is known about what it does.

Light is the most familiar form of solar radiation

A. What is the Velocity of Light and How is it Measured?

From everyday experience you know that light travels much faster than sound. Your sense of sight, which, as you know, depends upon light waves, may have convinced you of this. You may have seen a flash of lightning and waited for the crash of thunder. You may have seen steam escaping from the whistle of a distant engine or boat, and have waited possibly as much as four or five seconds before the sound of the whistle reached you. From these and other observations you might say that the speed of light is instantaneous, or immediate. Certainly there are no ordinary observations of phenomena on earth that suggest anything else. But when observations are taken across great distances, such as those which measure the orbits of the earth and other planets, there is positive evidence that light does not travel instantaneously. As a matter of fact, it travels with a definite speed, and this speed may be measured.

The speed of light is not instantaneous

Back in the seventeenth century a Danish astronomer named Römer was observing the moons of Jupiter. This planet, as you know, has nine satellites, four large and five small. Römer was trying to find how long it took one of these satellites to make one revolution around the planet. Since the orbit of this one satellite, the orbit of Jupiter itself, and the orbit of the earth are all nearly in the same plane, there is a time when the satellite is behind Jupiter and out of sight from the earth. Römer reasoned that since this was so he should be able to find the period of revolution by recording accurately the time from one disappearance of the satellite behind Jupiter to the time of its next disappearance.

Now look at Fig. 228, which illustrates the types of observations Römer made. Notice that one set of observations may be made when the earth is in position *A*. An-

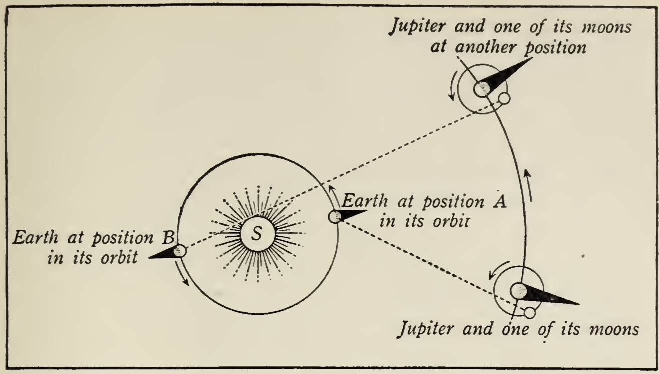


Fig. 228. Römer First Calculated the Speed of Light by making Observations of the Moons of Jupiter

This diagram is explained on pages 444–445

other set may be made when the earth is in position *B*. If light travels instantaneously, there should be no difference in the time of the disappearance of the satellite, regardless of where the observations are made. But, strange as it may seem, Römer found that there was a difference. If he predicted from observations at position *A* the time at which the satellite should disappear, when observed from position *B*, he would find that the satellite disappeared about 16 minutes (1000 seconds) later than predicted.

Why should there be this difference in time? Römer decided that it was due to the fact that the light from Jupiter had a greater distance to travel when the earth was in position *B*. Thus he came to the conclusion that light does not travel instantaneously.

While Römer made many observations, it is easiest to explain how he figured the speed of light from just the two indicated above. Remember that the earth is about 93,000,000 miles from the sun. Notice in Fig. 228 that in position *A* the earth is on the opposite side of the sun from position *B*. In other words, at position *B* the earth is

186,000,000 miles farther from Jupiter than it is at position *A*. Do you see why this is so?

Now recall that Römer found a difference of about 1000 seconds in the disappearance of the satellite between positions *A* and *B*. Put these two facts together and you can see that light travels 186,000,000 miles in about 1000 seconds. Simple division will give you the speed of light as about 186,000 miles a second.

This is a large figure and may not mean much to you. Let us put it in another way. The circumference of the earth is about 25,000 miles. Light travels in one second a distance equal to $7\frac{1}{2}$ times around the earth. On the earth you may see objects a few miles away. In the clear air of the mountains it is possible to see objects 100 miles or more away. The time interval during which light travels 100 miles is so short, however, that it seems to be instantaneous.

The speed of light is about 186,000 miles a second

Since Römer's observations the velocity of light has been determined by other methods. The most accurate work was done by Michelson of the University of Chicago. In one of his early experiments he measured very accurately a distance between points on two mountains and found it to be almost exactly 22 miles. He sent a beam of light from one mountain to the other, as shown in Fig. 230, and had the light reflected by a mirror. The distance out and back was 44 miles. He found that light traveled this distance of 44 miles in almost exactly $\frac{1}{4230}$ of a second. This, as you may see, is equal to a little more than 186,000 miles in one second ($4230 \times 44 = 186{,}120$). The value reported by Michelson was 186,284.

With these figures in mind, it is easy to understand why light seems to travel instantaneously. A flash of lightning 40 miles away is registered on the retina of your eye in less than $\frac{1}{4000}$ of a second. The brain cannot recognize such short intervals, but this time interval may be measured very accurately by scientific instruments.

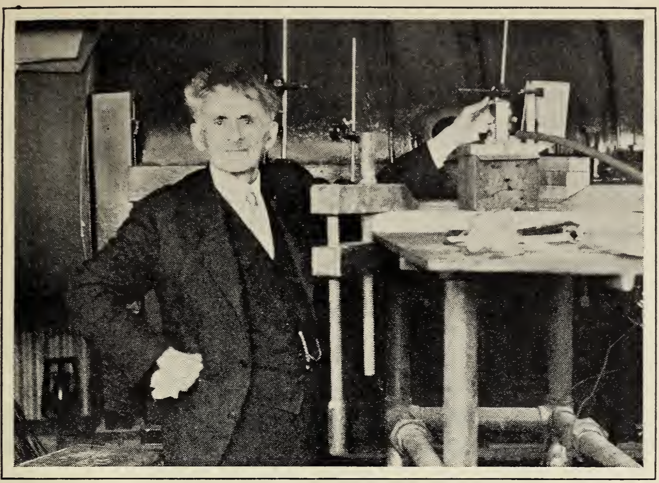


FIG. 229. ALBERT MICHELSON, *who measured the Fastest Thing in the World, and who measured also one of the Largest* (*1852–1931*)

ON A spring day in 1931, at his home in California, there died a man nearly eighty years old. But he was not old, really, and the work he had planned for himself was not nearly finished. Only the week before he had been commuting fifty miles each day to his work. And a strange work it was, too—sending beams of light back and forth from mirror to mirror through a vacuum tube a mile long! He wanted to measure again, and even more accurately than he had done it before, the speed of light, fastest of all things in the universe. Michelson was a German by birth, but was educated in the United States and graduated from the Naval Academy at Annapolis. For nearly forty years he was professor of physics at the University of Chicago. While there he devised among other things a piece of apparatus called an interferometer. By means of the interferometer, and knowing the length of light waves, Michelson measured in 1920 the diameter of Betelgeuse, that bright red star in Orion's shoulder. This was the first star, except our own sun, whose size had been determined. That point of light turned out to have a diameter of more than 200,000,000 miles. Can you imagine the sun's being so large that it extended in the heavens beyond the planet Mars? It would if it were as large as Betelgeuse. Michelson was the wizard who measured the giant. During the last decade other men, using Michelson's methods, have measured other stars. And other men have completed his experiments with the vacuum tube in California.

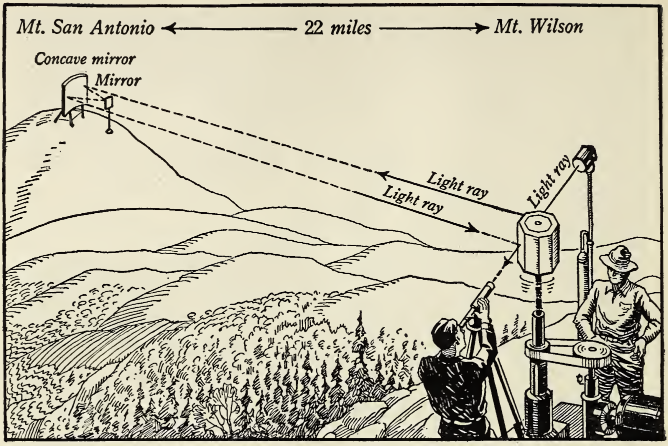


Fig. 230. Michelson determined the Velocity of Light by Means of Instruments

B. How do Light and Other Forms of Radiant Energy Travel?

Since the development of radio we have come to speak frequently of wave length. In ordinary broadcasting, the radio waves range in length between about 200 meters and 600 meters. There are special purposes for which waves longer than 600 meters are used. Television uses waves ranging from 100 to 200 meters. The short-wave sets use waves within the range of 20 to 100 meters.

The true character of radio waves is not fully known. It is known, however, that these waves are a form of energy, for receiving sets may be constructed which will act in response to effects which they produce. Light waves, apparently, are similar to radio waves but very much shorter. They seem to travel through space in somewhat the same manner as a wave moves along a rope when you move one end of the rope up and down quickly. Look at Fig. 231. The wave length is the distance between *A* and *B*. In the

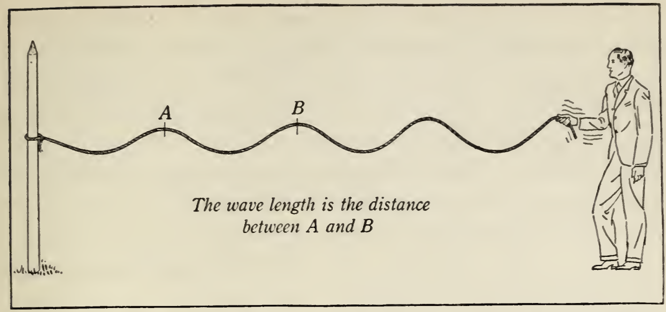


FIG. 231. Waves of Radiant Energy seem to move through Space in somewhat the Same Manner as Waves move along a Rope when you move One End up and down Quickly

How was the wave length determined in this diagram?

case of the rope the wave length may be one meter. In this wave motion an impulse of energy moves along the rope. The rope does not move toward the block. A point on the rope simply moves up and down. Radio waves are much longer than the waves in the rope. One meter is a little more than three feet. A wave of 500 meters is more than one fourth of a mile in length.

Light waves travel like radio waves. As already stated, they are very much shorter. The shortest waves used in radio are about 20 meters (more than 60 feet). The longest light waves are only $\frac{1}{12,500,000}$ of one meter (0.0008 millimeter.) The shortest light waves are one half as long (0.0004 millimeter). Notice that the longest light waves are twice as long as the shortest. The receiving set of a radio is sensitive to radio waves; that is, it is easily affected by them. The human eye and a photographic film are sensitive to light waves.

X rays are shorter than light waves. Those used to take pictures of bones, like the one shown in Fig. 232, are about $\frac{1}{10,000}$ as long as the shortest light waves. There are waves (the cosmic rays) even shorter than the waves of the X ray.

There are also waves longer than the ones used in radio. There is, in fact, a continuous range of waves from those as short as one trillionth ($\frac{1}{1,000,000,000,000}$) of a meter to those at least as long as 352,000 meters, or about 200 miles. It is not necessary to remember these figures themselves. It is enough merely to recognize the fact that the waves of different forms of radiant energy range in length from extremely short to very long.

There are great differences in the wave lengths of the different kinds of radiant energy

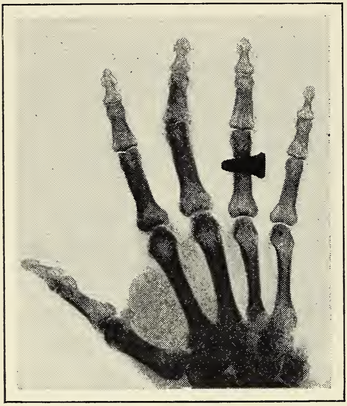


Fig. 232. X Rays are used to take Pictures of the Bones of a Living Person

What other uses for X rays are you familiar with?

All these waves, however, from the longest to the shortest, travel through space as wave motion, and all travel at the same speed.

The top of Fig. 233 represents the total range of the wave lengths of radiant energy. Along this line has been indicated the range of the various forms of radiant energy discussed in this section. Notice what a very small portion of the entire range is light, although this is the most familiar form of all radiant energy. Do you wonder that scientists are so interested in learning more about the other forms of radiant energy on this scale?

There is one more property which should be considered in relation to these waves of radiation. You have heard a radio announcer broadcast that the station from which he is talking is operating on a certain frequency. Do you know what this means?

Perhaps the meaning of frequency may be made clear by reference to a diagram. Look at Fig. 234, which represents

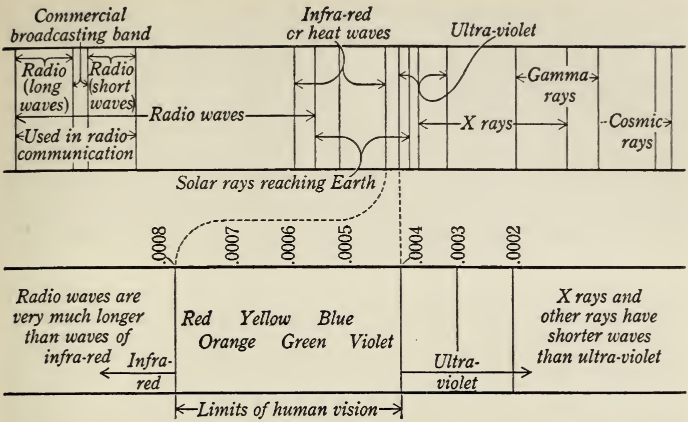


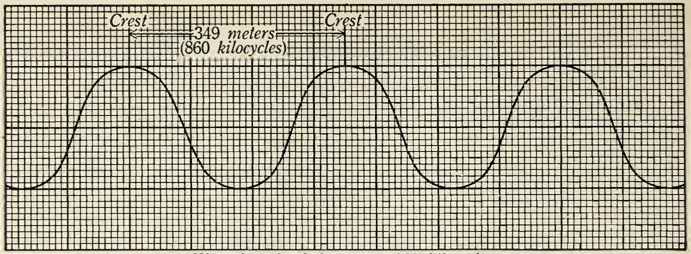
Fig. 233. Light is a very Small Portion of the Total Range of Wave Lengths of Radiant Energy

The bottom section shows more completely a small part of the total range

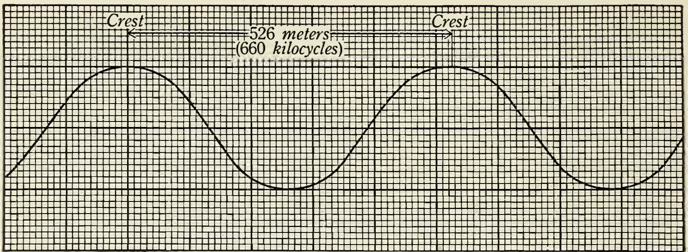
two typical waves of radiant energy. As you can see, one of these has a short wave length, while the other has a long one. Now remember that, regardless of their length, these waves are traveling through space at the same speed of about 186,000 miles per second. It should now be plain that more short waves than long ones pass a certain point in a given period of time. In other words, the rate of vibration is greater in the case of the shorter waves than it is in the longer. To put it in another way, the frequency of the shorter waves is greater than the frequency of the longer waves. Which of the waves in Fig. 234 has the higher frequency?

Waves of radiant energy differ in frequency of vibration

Differences in frequency, then, are really differences in the rate of vibration. This rate, in turn, depends upon wave length. The frequency of the vibrations may always be found by dividing the wave length into the velocity per second. Let us use an example here. Wave length is



Wave length = 349 *meters* (860 *kilocycles*)



Wave length = 526 *meters* (660 *kilocycles*)

Fig. 234. Two Typical Waves of Radiant Energy

Which of these has the higher frequency? Could you say that either of these waves is a mile long?

Frequency is determined by dividing speed by wave length

commonly given in meters, so velocity must be given in metric units. The velocity of light (186,000 miles per second) is 299,800,000 meters per second. A wave 100 meters long and a wave 200 meters long travel through space at the same rate of speed, namely, 299,800,000 meters per second. On the radio page of the newspaper, frequency is given in kilocycles. One kilocycle is 1000 cycles. The frequency of the 100-meter wave will be 299,800,000 ÷ 100, or 2,998,000 cycles. In this illustration you say that the frequency of the 100-meter wave is 2998 Kc. (kilocycles) per second. The frequency of the 200-meter wave, however, is only 1499 Kc. Do you see why this is? One of the big radio stations broadcasts

on a wave length of 370 meters. In this case the frequency is 810 Kc. Can you explain why?

If you will notice again the wave lengths referred to in this section, it should be clear that the frequency of vibrations in the case of light waves is several billions of times per second. The frequency of X rays is even greater than this. The frequency of cosmic rays is still greater. In each case, however, the frequency is determined in the same manner. It is the speed divided by the wave length.

C. How does Light affect a Photographic Film?

You have now seen many evidences of the effect of radiant energy upon atoms and molecules. Radiant energy causes many of the changes going on around you. The chemical change that takes place in the green leaf, in which carbon dioxide and water are changed to sugar and oxygen, takes place only when radiant energy is shining on the leaves. There are other observations that illustrate the chemical effects of the sun's rays. Linen cloth may be bleached by exposing it to sunlight. The substance that causes the color is destroyed by chemical action caused by light waves. Sunlight causes colored cloth to fade. Sunburn is caused by chemical changes in the matter that composes the cells of the skin.

The chemical changes caused by solar radiation may be shown even more clearly in the process of photography. If you own a camera you know how carefully you must protect the film against light. You may have gone to a great deal of trouble to secure what you thought would be especially fine snapshots, only to have your films come back light-struck. Why should this happen? What is film? What is the process by which pictures are recorded?

A film is a thin sheet of transparent material. Over this material has been spread an even coating of a chemical substance called silver bromide. This substance is extremely

sensitive to light, so the films are made in a dark room. When the film is exposed to light, as when a picture is taken, the light causes a chemical change in the silver bromide. The part of the film exposed to brightest light is changed most. The changes caused by exposure produce no visible effects on the film, but when the film is developed the effects are readily apparent. In this chemical change some silver is formed from the silver bromide. Most silver is formed on the part of the film that was exposed to most intense light. The dark part of a developed film is a deposit of metallic silver.

Photographic films are sensitive to light

The developed film is a negative. The image of white objects is blackest and the image of black objects is lightest. The reason for this is that white objects reflect most light and black objects reflect almost no light. The light reflected from light-colored objects affects the film most. Since so little light is reflected from dark-colored objects, the light from these sources affects the film least.

The picture that finally appears on the print paper is made in the same way as the picture on the film. The negative is placed over the print paper. Light shines through the negative and affects the chemical substance on the paper. The part of the paper that is covered by the darkest part of the film is affected least by the light that shines through. Objects that are black on the negative are light on the print. The changes caused by the light are evident in the picture that finally appears on the print paper. The process by which the picture appears on the paper is the same as the process by which it appears on the film. The photograph is composed of silver. There is most silver where the photograph is blackest.

Fig. 235 represents a negative and a print. This is a picture of a woman in an automobile. The woman is wearing white clothing. The automobile is dark in color. The light rays strike all these surfaces and are reflected in

Fig. 235. Both the Negative and the Print of a Photograph are formed by the Action of Light on Silver Bromide

Why should the print (left) be different from the negative (right)?

a varying degree. The most light comes from the white clothing. This light produces the greatest effect on the silver bromide. Thus more silver is formed. The darker automobile, however, reflects less light. Therefore less silver is formed by the rays reflected from the dark auto. On the print things are opposite to what they are on the negative. Light objects appear light and dark objects appear dark.

Light changes silver bromide to silver

The changes that take place in photography are in many respects remarkable. In snapping a camera the shutter may be open for but $\frac{1}{100}$ of a second or, with special cameras, for even a shorter interval. In this short time chemical changes take place which register accurately every part of the object that is photographed. During this short interval light is traveling through the shutter at the velocity of 186,000 miles per

The chemical changes in photography are due to very small impulses of radiant energy

second. The average length of the light waves is about 0.0005 millimeter or 0.000002 inch. In $\frac{1}{100}$ of a second a train of waves 1860 miles long will pass through the lens. Within each inch of this train there are about 50,000 wave impulses, or cycles. It is the energy in these waves, transformed in the atoms, that causes the chemical changes. If the shutter is kept open for a longer time more waves will enter, and more waves will cause greater changes.

Experiments with light waves of different wave lengths show that the shorter waves produce the greatest effects on the silver bromide. The effects from exposure to violet light for one second are about equal to the effects from exposure to red light for forty seconds. If you develop your own film in a dark room you use a red light. A short exposure to the dim red light does not noticeably affect the undeveloped negative. A short exposure to direct sunlight completely destroys it.

D. How is the Energy of Solar Radiation changed into Heat Energy?

Modern theories take it for granted that all matter is composed of molecules, and that molecules in turn are composed of atoms. You may know, too, that in the electron theory it is supposed that an atom is an electron, or a number of electrons, moving around a central nucleus, or core, somewhat similar to the manner in which planets move around the sun.

Now you may ask, "What is the effect of radiation upon this structure called the atom?" It is obvious that the sun's rays produce heat, and that a hot object radiates heat. There is no satisfactory answer, however, to the question of how radiant energy is changed to heat or the reverse.

One interesting and useful theory explains these phenomena as resulting from the influence of waves of radiation

upon the paths of the electrons within the atoms. What does this mean? Let us see.

First of all, recall that heat is the energy of moving molecules. Radiant energy makes the molecules move more rapidly. As they move faster, the temperature of the substance rises. As the temperature lowers, the process is reversed. The molecules radiate energy as they lose heat. Loss of heat is loss of energy, and so they move more slowly. The process of changing gases to liquids, as in making liquid air, is a process for removing energy from molecules.

Heat is an effect of radiation upon molecules

Now come back to the theory. It supposes that the electrons in an atom move about a central nucleus in orbits somewhat similar to the movements of the planets about the sun. A gain in molecular energy occurs when an electron moves outward from the nucleus and thus moves in a larger orbit. This change in the path of the electron takes place when energy is transferred from the radiant waves to the atom, and to the molecule of which the atom is a part.

This increase in energy causes the molecule to move faster. It has more energy, and this energy is what we call heat. The molecule loses energy by radiation; that is, it gets cooler when an electron moves inward toward the nucleus and thus moves in a smaller orbit. The loss of heat occurs, then, when energy leaves the molecule. The energy of all forms of radiation may be changed into heat energy, but most of the heat from the sun comes from the invisible infra-red rays.

The energy of solar radiation, after passing through millions of miles of space, seems to be transferred to molecules through the tiny particles of matter known as electrons. This energy in turn is the source of the forces that wear down mountains. Thus you see that the energy for the mightiest forces is transferred through the smallest particles.

E. Why is it Healthful to Play in the Sunshine?

You have now learned that the energy of solar radiation causes, through the electron, a change in the energy of atoms and molecules. Are these changes reflected in the processes of life? What have they to do with the health and well-being of the human organism, for example? Is exposure to the rays of the sun healthful or harmful?

If you study the entire range of the wave lengths in solar radiation from infra-red to ultra-violet, you will find that different wave lengths produce different effects on living cells. The character of some of these effects is well known.

The energy of infra-red rays is changed to energy of heat in the molecules that compose the outer cells of the skin. If these rays are intense they produce on the skin a dry and disagreeable feeling of heat. Next to the infra-red are the waves of visible light. The important thing about these rays is that their effect is interpreted by the brain as vision. Light waves, even if the infra-red and ultra-violet have been filtered out, produce an agreeable feeling of heat when applied to the bare skin. Next to the light waves come the ultra-violet. These do not penetrate deeply, but when too intense they produce a most disagreeable effect. Sunburn is largely an effect from ultra-violet rays. When used in proper concentration, however, the ultra-violet rays have a wholesome effect upon the well-being of living things.

Radiant energy in sunshine produces vitamin D in the body

A most important effect from the ultra-violet is that these rays have the property of changing a substance called ergosterol, which is present in the cells of the skin, into vitamin D. You know that vitamin D is essential to the formation of healthy bones. The lack of it causes the disease known as rickets. Children who do not spend enough time in sunlight are likely to suffer from this disorder. Vitamin D is contained in cod-liver oil. It is important to know that children suffering from rickets are benefited alike by

taking cod-liver oil and by exposure to ultra-violet rays. The rays from an arc lamp or a mercury-vapor lamp, such as that shown in Fig. 236, are rich in ultra-violet. Not all lamps advertised as sun-ray lamps are suitable for such treatment, however. It is best to secure reliable medical advice before attempting treatment of this kind. A proper type of lamp may be effectively used in treating children suffering from rickets. The ultra-violet rays increase the percentage of calcium and phosphorus in the blood. These elements are essential to healthy growth of the bones.

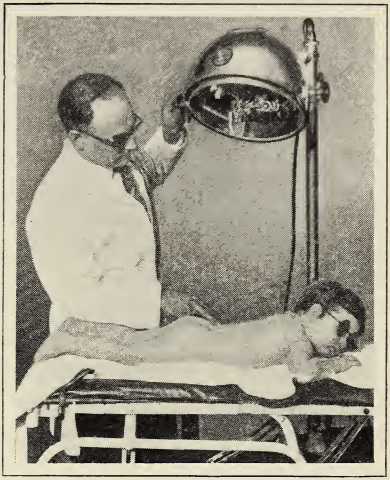


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FIG. 236. The Rays from an Arc Lamp or a Mercury-Vapor Lamp are Rich in Ultra-Violet

Why are such rays beneficial to health?

There are other wholesome effects that come from exposure to ultra-violet rays. This treatment increases the power of the blood to destroy disease germs. There is good evidence that this serves as a protection against colds and other forms of illness, especially tuberculosis. It should be borne in mind, however, that an overdose of ultra-violet seems to lessen the natural powers of the body to fight bacterial illness. It is important to remember this when using a sun lamp. You must not think that "if a little will do good, more will do better."

Ultra-violet rays have a beneficial effect upon human life

These rays have the power to kill germs, but since they do not penetrate the skin the effect is only on the sur-

face. In addition, this treatment seems to give a sense of well-being and to develop an increase in mental alertness. The effect is similar to that which comes from exercise in pure, clear air of the out-of-doors. All these effects illustrate the wholesome influences, favorable to healthy living, that come from play out of doors in the sunshine.

You should not confuse ultra-violet lamps with ordinary lamps such as are used for lighting. No ultra-violet rays are given off from ordinary lamps. You should know too that false claims are often made for "health lamps." Some lamps have been sold for health treatment that are of no more value than the lights used for house lighting. Ultra-violet lamps should be purchased only from responsible dealers, and they should be used only under the advice of a capable physician.

X rays too have an effect on living cells. Under proper control these rays are used in treatment of some forms of cancer. They have been used with doubtful success in treating other disorders. Burns from X rays, however, may be serious, and X-ray lamps must be used with caution.

Radiant energy is found in many forms. It travels in waves of varying length. The speed of these waves through empty space is always the same. Solar radiation is a very familiar form of radiant energy. The energy of solar radiation produces many effects upon the earth. Energy for the forces that wear down mountains and energy that is essential to the vital processes in living things have their origin in this source.

Can You Answer these Questions?

1. How many different forms of radiant energy do you know? How are they alike? How are they different from each other?

2. What is the velocity of light in miles per second? in kilometers per second? How has this been determined?

3. In speaking of the radio, what is meant by a wave length of 250 meters? of 570 meters?

4. What is meant by frequency? What is the relation between frequency, speed, and wave length?

5. A certain radio station broadcasts upon a wave length of 526 meters, and at a frequency of 570 Kc. What do these figures mean? Is there any relationship between them? What is the product when you multiply wave length by frequency? Why is this figure the same as the speed of light?

6. What explanation is there for heat in terms of the molecular, the atomic, and the electron theories?

7. What is a photographic film? What changes take place upon it when it is exposed to light? when it is developed?

8. What is the difference between the negative of a photograph and the finished print?

9. Why is red light used in the dark room while developing pictures?

10. What are X rays?

11. How does the frequency of light waves compare with the frequency of radio waves?

Questions for Discussion

1. What do you think happens to the waves of solar radiation as they pass into space, farther and farther from the sun?

2. Could you see an object in the dark when it is giving off infra-red rays? Why?

3. In this chapter heat is explained in terms of the movement of molecules. Should you call this explanation a hypothesis, a theory, or a law?

4. Which do you think is more sensitive to light, the human eye or the film of a camera?

5. Can you trace the steps by which solar radiation is changed into the energy that wears down mountains?

6. In the rays from an ordinary electric light are there more ultra-violet rays or more infra-red rays?

Here are Some Things You May Want to Do

1. Astronomers refer to the distance to stars in terms of light years. Find out what a light year is, and why astronomers use it as a unit of measurement.

2. Find answers to these questions:

a. How much faster does light travel than sound?
b. How long does it take for light to reach the earth from Arcturus? from the sun? the moon? Venus? Pluto?

3. What is the difference between short-wave radio broadcasting and regular broadcasting?

4. Have you ever seen photographs taken in natural color? Perhaps you have seen color movies, such as the technicolor. How does this method of photography differ from the method described in this chapter? Prepare a report on color photography.

5. Examine a camera. Explain the adjustments that are made for taking pictures in bright light and for taking pictures in dim light. What is the condition of a film that has been overexposed?

6. Make a pinhole camera and demonstrate how it may be used.

7. Print some pictures from negatives you may have.

8. Find out how blue prints are made, and explain the energy changes that take place in the process.

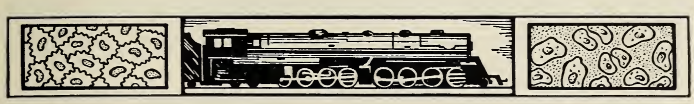
Gabriel Moulin

FIG. 237. These Giant Trees of California have grown from Small Seeds

This unit will explain the processes which make such growth possible

UNIT VI

What has Man learned about the Story of Life?



Chapter XXI · How do Living Things use Energy?

Chapter XXII · What is the Origin of Food and How is it used in the Cells?

Chapter XXIII · How does the Body function Normally? How is it influenced by the Effects of Alcohol, Tobacco, and the Drugs used in Medicines?

WHAT should you expect a unit on the story of life to tell you? It might begin with the story of primitive man and trace the development of man's control over the forces of his environment through many centuries. Such a story of life would be the story of energy and machines. It would be a story of man continued from the time when he secured a bare living from scratching the soil until now, when he uses enormously complex agricultural machinery to plant and harvest his crops. In addition, such a story might trace man's progress in transportation, communication, and industry from early times until the machine age of today.

Another life story, bits of which you have read in this book, could deal with the races of men, where they came from, and how they spread over the world. Today, as you know, there are many different races. It seems more than possible that at one time there was only one. This story of life, then, would trace the development of mankind.

Still other life stories might be unfolded about plants and animals, and about the earth and the changes that have taken place upon it.

The present unit, however, deals with none of these but with the story of life processes themselves. What are life processes? A seed falls from a tree. Perhaps it finds suitable soil and takes root. With the aid of sunlight and moisture it begins to grow. As time goes on, a tiny tree develops. After years of growth a giant tree has come from the small seed. How did this growth take place? Where did the energy come from that made growth possible? How was this energy transformed and used? As another example, recall again the life cycle of the frog which you studied in an earlier chapter. An egg develops into a tadpole and finally into an adult frog. How did this happen? Is energy used by a frog? If so, where did it come from? How was it, in turn, transformed into the energy of living things? You can doubtless think of other life processes equally difficult to explain. It is the story of these processes with which this unit is concerned.

Chapter XXI · How do Living Things use Energy?

In several earlier chapters you have found the statement that all the earth's energy came at some time from the sun. Throughout this book you have seen how solar energy flows over the earth. In the last two units you have seen many effects of radiant energy, especially as it affects nonliving things. You have seen how mountains are worn down and raised again, how definite climatic changes have taken place, and how radiant energy in many different forms influences life upon earth.

These and other phenomena illustrate the effect of energy on nonliving things. But energy, as you know, has also a vital relation to living things. In fact, the most striking property of living things as distinguished from nonliving is their ability to use energy in the processes of life and growth. Let us study this a little further.

If you recall some of the things you have learned about plants and animals, you realize there is a necessary relationship between nonliving and living things. As rocks are broken up by forces resulting from solar radiation, they form soil. This soil provides material necessary for plant and animal life. Solar radiation itself furnishes the warmth and moisture so essential for growth. In other words, solar radiation is absolutely necessary for the processes by which nonliving things are changed into living things. Indeed, it is possible to follow the flow of energy from its source in the sun through the cells of our own bodies, or through the cells of any other living things. Can you follow it? Look at Fig. 238.

Energy is stored as nonliving things are changed into living things

Food, as you know, is essential in providing for energy and growth. You may be familiar with some of the processes

Fig. 238. Can you trace a Cycle of Solar Radiation in this Picture?

by which food is made in the green cells of plants. Perhaps you know something of the manner in which foods are used in living cells. You should recognize these processes as continuous. Foods are carried in the blood stream to the cells. These foods contain energy. As the foods are used, energy is released. Waste products formed during this process flow away from the cells. These wastes may be used again by green plants as material from which more food is produced. And so the cycle continues.

It is the process by which energy is used in living things that we shall study a little more fully in this chapter.

A. What is Life?

This is not a simple question. The story of man's attempts to answer it is probably as long as the story of man himself. Even yet, no one can answer it simply or definitely. Life shows itself in a great variety of forms. We can describe

life, and we can talk about it. But when we try to answer directly the question "What is life?" we soon find that we have only a partial answer. In some respects all living things, plants and animals, are alike. In other respects they are unlike. Let us look at some of these similarities and differences.

B. What Processes take place in the Cells of a Green Plant?

Have you ever wondered as to just how a plant grows? Many people have. As one studies the conclusions concerning plant growth one sees once more how man's knowledge has gradually increased.

Back in the time of the Greeks, Aristotle taught that the food of plants was prepared in the soil and supplied to them in solution, through their roots. As far as the plant itself was concerned, thought Aristotle, it had nothing to do with making food; it merely used what came to it in solution.

At the end of the sixteenth century, a chemist named Van Helmont decided to test Aristotle's explanation by experimenting. This experimenter placed a small willow tree, weighing 5 pounds, in dry soil. The soil in which he set the tree weighed 200 pounds. When the experiment was started, the tree and the soil weighed 205 pounds. The tree was allowed to grow for five years. During this time nothing was added but water. At the end of this time, both the tree and the dry soil were carefully weighed. The tree was found to weigh 169 pounds, but the soil, when dried again, was found to have lost only two ounces.

Aristotle believed that a tree secured its food in solution from the soil

Van Helmont interpreted this observation as proving that the tissues of a plant are formed chiefly from water. His conclusion was, of course, only half correct, but his experiment proved that Aristotle too was wrong. His experiment, judged by modern standards, was inadequate. Never-

Van Helmont believed that a plant made its own food

theless it is important, because it was one of the first cases in which the experimental method (using an experiment to test an idea) was used in trying to solve the problems of plant life.

To us today it seems strange that Van Helmont should have missed another point in his experiment. He was one of the first to recognize the existence of carbon dioxide. He knew that the atmosphere is composed of a mixture of gases, but he failed to see the relationship of any of these gases to plant growth. Van Helmont should not be criticized, however. We should realize that his work illustrates very clearly the slow, painful steps by which the knowledge we now possess has been gained.

We know today that changes which go on inside the green leaves of a plant are essential to the life of both plants and animals.

Are there evidences of life in a green leaf? If you could examine a leaf of a healthy green plant through a microscope, you would see some evidence that the leaf is alive. Let us in imagination examine such a leaf and see what we can find out about the life processes of plants.

In Fig. 239 is shown a photograph of a section of a common water plant called *Elodea* or *Anacharis*, as seen through a microscope. In Fig. 240 the artist has drawn a similar section in order to show it a little more clearly. This is a good plant to observe, for its leaves are thin, and light will show through them. Notice that the leaf is made up of many little compartments, or divisions. Notice too that each compartment contains a thin watery fluid. These compartments, together with the materials with which they are filled, are called cells. Each cell of the leaf has a cell wall. The leaf, then, is a large number of cells fitted together.

Is there life in one of these cells? There seems to be, for you can see motion within the cell. The living stuff of the cell is the fluid substance within it. This substance is called protoplasm. All the material inside the cell wall is proto-

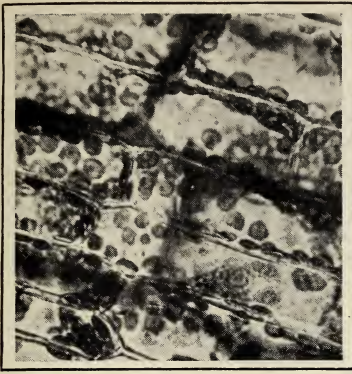


Fig. 239. A highly Magnified Section of an Elodea Leaf, showing the Cell Walls and Chloroplasts

Can you find in this photograph all of the things shown more distinctly in Fig. 240?

Fig. 240. Can you find in Fig. 239 the Different Parts of the Green Leaf indicated in this Drawing?

This drawing of the same leaf shows more clearly the composition and structure of the cells

The living stuff in a cell is protoplasm

plasm. As you go forward now and later in your study of living things, you will learn that the processes of life are processes of destroying and of rebuilding protoplasm. In the destroying of protoplasm, energy is released. In the rebuilding, energy is stored. Thus there is a cycle of life within the cell. But where does the material which composes the protoplasm come from, you may ask. The answer is, from plant food.

Chloroplasts are a part of protoplasm

As you look at the magnified section of your leaf, you see that a cell seems to contain a great number of little bodies, intensely green in color. These little bodies are called chloroplasts. They can easily be seen as part of the protoplasm in the cells of a green leaf. Do you see them in Fig. 239? It is these chloroplasts which furnish evidence of life within the cell, for they are constantly moving about in the protoplasm. Since they are moving, it should be obvious that the cell is using energy, for energy is necessary for motion.

These chloroplasts are composed of chlorophyll. Chlorophyll is an extremely important substance. The cells containing it can use the energy of sunlight and manufacture sugar from carbon dioxide and water. Cells that do not contain chlorophyll cannot make food. The food of all living things comes directly or indirectly from sugar that is manufactured in green plants. Chlorophyll is therefore essential to the existence of all plants and animals.

Chloroplasts are composed of chlorophyll

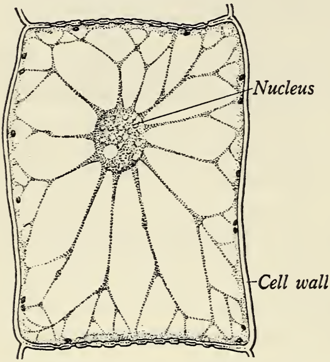


Fig. 241. In Each Plant Cell there is a Denser Portion called the Nucleus

So far your examination of this leaf has shown you that it is composed of cells, and that these cells are filled with protoplasm. The protoplasm contains a great number of chloroplasts, green in color. There are so many of these, in fact, that the leaf itself is green. These chloroplasts in turn are composed of chlorophyll. The leaf, then, is not so simple after all.

In your examination of a plant cell you may see that not all of the colorless matter is of the same firmness. In each cell there is a denser portion called the nucleus. It is not always easy to see the nucleus in a living cell, but through a microscope it may be seen easily in specially prepared slides of dead cells. The drawing in Fig. 241 was made from such a slide. You may study the work of the nucleus at a later time.

There are thousands of cells in a single leaf of *Elodea.* Look at Fig. 239 again. The plants that grow in the field and in the forest are also composed of cells. Some plants, including bacteria and some of the algæ, are composed of but a single cell. Cells may be of different shapes, as shown

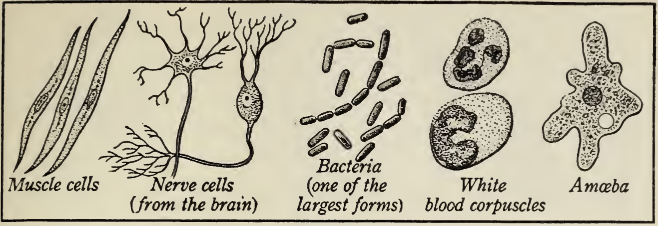


FIG. 242. There are Many Different Kinds of Cells

Only a few are shown here

in Fig. 242. They may live singly, as in bacteria, or they may live in groups, as in *Elodea*. But in one respect all cells are alike. All are alike in that each is composed of protoplasm. Each cell can build protoplasm from food, and each can use protoplasm in the processes through which energy is released.

All cells contain protoplasm

C. What Processes take place in the Cells of Animals?

Imagine now that you are examining an animal cell with a microscope. Such a study is possible by using the single-celled animal called *Paramecium* (plural, *paramecia*), commonly found in stagnant water. This organism, greatly magnified, is shown in Fig. 243. Notice that this animal cell, like the plant cell, has a cell wall. Notice that the cell is filled with liquid and that within this liquid there is a denser portion, the nucleus. You may see "signs of life" in the cell, for you can observe motion of particles in the liquid. In appearance the liquid is changing continually. Another more obvious sign of life is that this little animal is an active swimmer. The liquid of which the animal cell is composed is living stuff. It too is protoplasm. All living cells — plant and animal — are alike in that they are composed of protoplasm.

***Paramecium* carries on all the life processes**

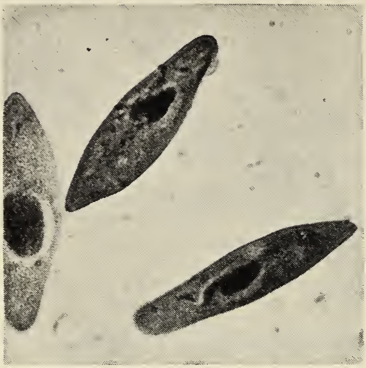


Fig. 243. These are Paramecia, as photographed under a Powerful Microscope
Do they look like the drawing in Fig. 244?

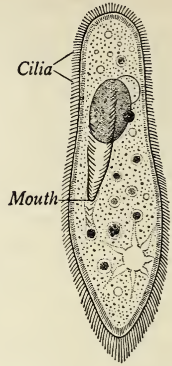


Fig. 244. Compare this Drawing of a Paramecium with the Photograph in Fig. 243

If you could watch the tiny paramecium through an interval of time you might see it divide into two parts and become two paramecia, each like the parent only smaller. These young paramecia take food from the stagnant water in which they swim, and soon grow to the size of other paramecia. After a time each of these will divide and each will form two more. From what was originally one paramecium there are four in the third generation, as shown in Fig. 245. Each is as large as the grandparent and in every obvious particular seems just like it.

Within the cell of this little animal, proteins, carbohydrates, fats, mineral salts, and water are built into protoplasm. These food substances are taken into the cell from the water in which it swims. You may see a groove along one side of the body. This answers the purpose of a mouth. The animal feeds upon bacteria and upon some animal forms smaller than itself. These are present in the stagnant water where the paramecium lives. By chemical action inside the cell, the foods are digested. They are then made

The cell of *Paramecium* contains protoplasm

into protoplasm. These products that are formed from the digested foods make up the physical basis of life. Thus, by some unknown process, lifeless substances from without the cell are built into living stuff within the cell.

You may see through your microscope that *Paramecium* leads a very active life. It is continually busy swimming about in the drop of water. Now study Fig. 244, in which the artist has drawn the parts of the organism a little more clearly. Notice that the cell is completely covered with minute hairlike structures. These are called cilia. They are used to push the organism through the water. Energy is required for activity, and energy is released by a chemical action between oxygen and part of the protoplasm. Carbon dioxide and small amounts of other substances are released by this chemical action as waste products. These waste products pass out of the cell through the cell wall. *Paramecium* is constantly in need of food to replace the protoplasm that is used for release of energy, and it must have food to build new protoplasm. This food comes from plants that store energy from sunshine. Again you see that sunshine is necessary for energy. The processes that go on in this single cell are similar to those in other animals. Food is used and energy is released.

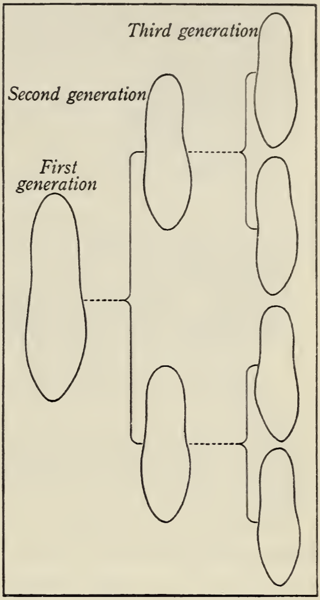


Fig. 245. In Time a Single Paramecium may be the Grandparent of Thousands of Similar Organisms

FIG. 246. Animals are Dependent upon Green Plants for Food

D. In What Respects are All Cells Alike? In What Ways do Cells differ from Each Other?

Protoplasm from all cells is very much the same

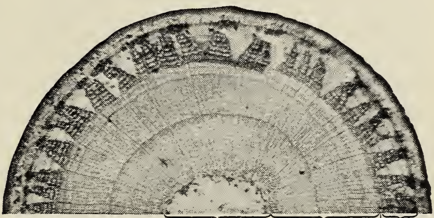
Careful examination shows that protoplasm from all cells, either plant or animal, is very much the same. Chemical analysis shows that it is mostly water. The common foods — proteins, sugars, and fats — are all found in protoplasm. Along with these are mineral salts, including chlorides, carbonates, and phosphates of sodium, potassium, calcium, ammonium, magnesium, and iron. Gaseous substances are also present. Of these, oxygen and carbon dioxide are of most importance. There is energy in foods. This energy is liberated by chemical action between the protoplasm and oxygen. As energy is released, some of the protoplasm is destroyed. Within the cell more protoplasm is formed from foods. The new protoplasm is used in the process of releasing energy.

One important difference between the cells of *Elodea* and that of *Paramecium* is that the cell of *Paramecium* does not contain chlorophyll. Without chlorophyll, these little animals are unable to manufacture food. They must have food, of course, but since they cannot make it they must depend upon green plants for their supply.

Some cells contain chlorophyll, others do not

All living things may be grouped in two great divisions. One has cells containing chlorophyll. The other does not. Living things containing chlorophyll manufacture foods from substances in the environment. Living things without chlorophyll must depend for their food supply on substances that do contain chlorophyll. Is Fig. 246 a familiar scene?

There are some plants (the group called fungi) that have no chlorophyll. These also are directly or indirectly dependent upon green plants for food. Plants that do not contain chlorophyll include bacteria, yeasts, molds, mushrooms, toadstools, and others.



Photomicrograph by E. C. Harrah

Fig. 247. One of the Regions of Growth in a Tree is directly beneath the Bark

Why does a tree usually die if the bark is removed?

The energy used by green plants, by fungi, and by animals comes from the sun. It is made ready for the use of the living cells through the agency of chlorophyll in the protoplasm of green plant cells.

These changes that go on within the single cell of *Paramecium* or in the cells of *Elodea* go on in much the same way in all living cells. You probably know that one of the regions of growth in a tree is just beneath the bark. Look at Fig. 247. The living cells there use the same kinds of

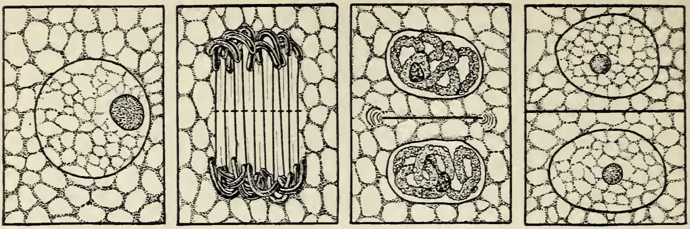


Fig. 248. Growth in a Tree Cell causes the Cell to divide and form More Cells

Notice the steps by which the single cell in *a* becomes two cells in *d*

food as are used by *Paramecium,* namely, carbohydrates, proteins, and fats. Water and the same mineral salts are also necessary. As in all living cells these are the materials from which protoplasm is made. There is activity within the cells. Chemical action of protoplasm and oxygen from the air supplies the energy. Some protoplasm is destroyed as energy is released. More protoplasm is formed from foods carried to the cells in the sap. Some of this is used to supply more energy to the cell. Some is used for growth. If you could watch the cells of the tree you could see that these cells, like *Paramecium* and the cells of *Elodea,* divide and form new cells. A cell wall forms between the new cells, but unlike *Paramecium* these cells do not separate. Taken together they form the trunk of the tree.

The growth processes are similar in all cells

In what respects are cells unlike? Obviously, there are differences between the cell of *Paramecium* and a tree cell. The similarities are in the fact that similar materials and similar processes are necessary for the life of either. But the products formed in the process of growth may be extremely different. Growth in the tree cell causes the cell to divide and form more tree cells, as shown in Fig. 248. Growth in the cell of *Paramecium* causes this cell to divide and form two paramecia.

Probably the most striking difference between the cell of *Paramecium* and the cells of a tree is in what we may call specialization. The cell of *Paramecium* is unspecialized. One cell does everything that is done. It gathers food, digests it, and builds up protoplasm. In the tree and in all many-celled plants and animals the cells are specialized. The cells of roots, stems, and leaves are different. Each is specialized to serve a particular activity, or function. A highly specialized cell cannot live alone. If leaf cells are cut from the stem, the leaf will die. If all the leaves are cut from the stem, the stem will die.

The cells of some organisms are specialized

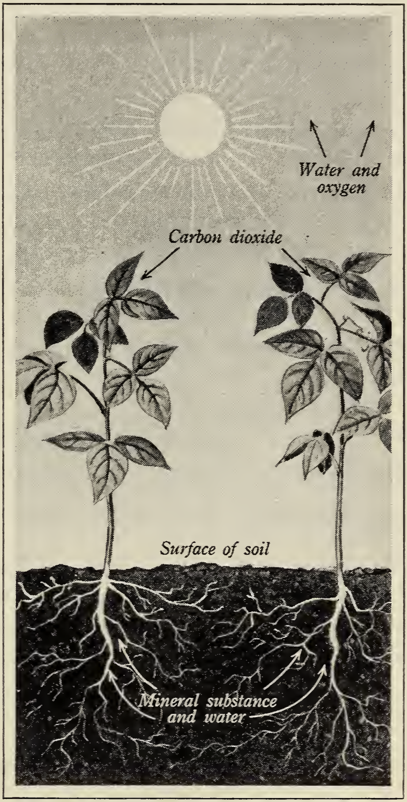


FIG. 249. The Processes of Life depend upon Various Factors in the Environment

Can you trace the life cycle here?

You might study the living cells in different parts of a tree. The cells of leaves and flowers are formed from the cells in the bud. New root cells are formed from cells in roots. In the leaves there are several different kinds of cells. Each of these serves a distinctly different function. The materials of which blossom and root cells are com-

posed are nearly but not quite the same. These slight differences make one a blossom cell and the other the cell of a root.

Similarly you may study the process of growth in higher animals. Your own body is composed of cells. Within each cell are going on the processes of growth and repair and the processes in which energy is released. The materials used in your body cells for these processes are essentially the same as the materials used in the cell of *Paramecium* or in the cells of a tree. As in the tree, many different kinds of cells are built from this common material, that is, from proteins, carbohydrates, fats, mineral salts, and water. There are muscle cells, bone cells, nerve cells, gland cells, and many others. Each is different from the others in the function that it serves, yet all are alike in origin. All of these cells are composed of protoplasm. This in turn is formed from food and water. All cells use food and oxygen to produce energy, and all of them use food for growth. In the process of growth they divide and form new cells.

Are you now able to answer the question "What is life?"? No. Yet you have a little better understanding of the processes which go on to produce and maintain life.

The living stuff in cells is protoplasm. Protoplasm may add food to itself and grow. Energy may be released from the chemical action of protoplasm and oxygen. Living things use this energy for activity.

Can You Answer these Questions?

1. Can you trace the cycle by which solar radiation becomes a part of living things?

2. What was Aristotle's explanation of the growth of plants?

3. What did Van Helmont do which disproved Aristotle's theory? Why was this experiment an important one? What gas from the air is used by plants in food-making?

4. What evidences are there that a green leaf is alive?

5. What is a cell?

6. What is protoplasm? Of what different substances is protoplasm composed?

7. What is meant by the statement that "the processes of life are processes of destroying and rebuilding protoplasm"?

8. What are chloroplasts? In what kind of cells are chloroplasts contained?

9. What is chlorophyll? What part does it play in plant life?

10. Are there any single-celled plants?

11. How are new paramecia produced?

12. How does *Paramecium* secure its food?

13. Do all plant cells contain chlorophyll? Do animal cells contain chlorophyll? What differences are there in life processes because of this?

14. Where does growth take place in a tree? During which season of the year are the largest cells formed?

15. In what respects are all cells alike?

16. In what respects are cells unlike?

17. What is meant by the specialization of a cell? Can you give any examples of cells that are specialized? Of cells that are not specialized?

Questions for Discussion

1. How should you answer the question "What is life?"?

2. The leaves of some plants are not green, but white. Are there any chloroplasts in the leaves of such plants?

3. You will notice that in this chapter protoplasm is referred to as "living stuff." Do you think that a more definite description might be given?

4. Can you trace the life history of *Paramecium*?

5. In what ways does the life history of *Paramecium* differ from the life history of a flower or a tree?

6. What should your answer be to each of the following questions?

a. Do all plants make their own food?
b. Do all living things use food?
c. Could animal life exist without plant life?
d. Do all plants contain chlorophyll?

Can you defend your answers?

Here are Some Things You May Want to Do

1. *Paramecium* is a very simple type of animal organism. There are others equally simple, however. Find out what you can about such organisms as *Amœba, Vorticella, Stentor,* and *Euglena.* Read about these in an encyclopedia.

2. Man did not always believe in the cell theory. The knowledge we have of it today is the result of many people's work. Among them are Robert Hooke, Hugo von Mohl, Robert Brown, and Louis Pasteur. Name one important contribution to knowledge made by each of these men.

3. If your school has a science laboratory with a good microscope, examine various things and see if you can find differences in the shape of cells. You might try onion skin, a very thin piece of cork, the petal of a flower.

4. Gather some stagnant water from a roadside puddle or from a swamp. Examine a drop of water from the sample under a microscope. Are there living things in it?

5. Keep some of the sample of stagnant water in a bottle in the room for several days. Observe the changes in appearance. After ten days examine a drop of the water under a microscope. Do you still find living things? Explain your observations.

Chapter XXII · What is the Origin of Food and How is it used in the Cells?

You may ask how it is that a muscle cell in your arm, a tree cell, or the cell of *Paramecium* can produce more cells. Each produces cells like itself and all from essentially the same material. How is this possible? This is a difficult question. It cannot be answered completely, but you can learn much about the processes that go on in living cells.

FIG. 250. Even this Prize Baby is the Result of Cell Growth

Do you think that good food has any effect upon cell growth?

All cells, regardless of their function, require food. In order to understand how the cells use food it is necessary to learn what foods are. You may know that there are six distinctly different kinds of foods. These are carbohydrates, fats, proteins, mineral salts, water, and vitamins. Each is essential to healthy functioning of the cells, for each is essential to the building of protoplasm. Three of these foods, namely carbohydrates, fats, and proteins, must be digested before they can reach the cells.

A. What is the Origin of Carbohydrates and How are they prepared by Digestion for Use in the Cells?

The most familiar carbohydrates are sugars, starches, and celluloses. These words are used in the plural, for there are several different forms of each. All the carbohydrates,

The Metropolitan Museum of Art

Fig. 251. When the Environment becomes Unfavorable for the Proper Supply of Food, Living Organisms Die

Schenck, the famous European painter, entitled his picture "Lost." Do you think this is a good title?

however, are similar in composition. All of them are composed of the same chemical elements, namely, carbon, hydrogen, and oxygen. In most carbohydrates, hydrogen and oxygen are present in the molecule in the relation of two atoms of hydrogen to one of oxygen. The chemical formula for the simplest form of sugar is $C_6H_{12}O_6$. The formula for cane sugar (the chemical name is sucrose) is $C_{12}H_{22}O_{11}$.

Molecules of sugar contain atoms of carbon, hydrogen, and oxygen

In the process of food-making, as you have learned, the simplest sugar, commonly called glucose [1] or fruit sugar, is made from carbon dioxide and water. During this chemical change, which goes on only in the green cells of a plant, oxygen is released. This chemical change may be shown by an equation:

Sugar is made in green leaves

$$6\ CO_2 + 6\ H_2O \longrightarrow C_6H_{12}O_6 + 6\ O_2$$

$$\text{Carbon dioxide} + \text{water} \longrightarrow \text{glucose} + \text{oxygen}$$

[1] In this discussion the term "glucose" is used to include dextrose, levulose, and galactose.

FIG. 252. Can you trace the Processes by which Substances in the Environment have been changed into this Field of Growing Corn?

In the plant, glucose may be changed to other forms of carbohydrates. In some plants, especially in sugar cane and sugar beet, some glucose is changed into cane sugar or sucrose. This is the common sugar that is used on our tables. Two molecules of glucose make one molecule of sucrose and one molecule of water. This also may be shown by an equation:

Complex sugars are formed from glucose

$$C_6H_{12}O_6 + C_6H_{12}O_6 \longrightarrow C_{12}H_{22}O_{11} + H_2O$$
$$\text{glucose} + \text{glucose} \longrightarrow \text{sucrose} + \text{water}$$

Carbohydrates in great abundance are stored in plants in the form of starch. Molecules of starch are formed in much the same manner as molecules of sucrose except that many molecules of glucose are required to form one molecule of starch. No one knows how large the molecule of starch is, but it is

Starch is formed from simple sugar

known that the molecule is some multiple of $C_6H_{10}O_5$. The formula is commonly written as $(C_6H_{10}O_5)_n$. The n outside the parenthesis stands for some definite but unknown number.

Starch differs from glucose or sucrose in that it does not dissolve in water. Have you ever tried mixing it with water? Starch is stored in plants, especially in seeds. Grains of wheat, oats, rye, and rice contain larger percentages of starch than of other foods. White potatoes, sweet potatoes, carrots, onions, celery, and some other vegetable foods are mostly, but not wholly, starch.

Cellulose is an indigestible carbohydrate

Cellulose, which composes the tough woody parts of plants, is similar to starch in that the molecule is some multiple of $C_6H_{10}O_5$. Both are insoluble in water, but starch is readily changed to a soluble substance by digestion. We cannot digest cellulose. It is, however, digestible to some extent in the digestive systems of cattle, sheep, goats, and many other animals. Even though we cannot digest cellulose, it makes up an important part of our diet. For healthy functioning of the digestive system we must use foods that are not too concentrated. Concentrated foods contain but little cellulose. Such foods are digested and absorbed, and but little of them is left in the intestine. Coarse foods contain cellulose, and the cellulose is left after the digested foods are absorbed. Some cellulose is necessary for healthy functioning in ridding the body of waste.

You have followed the processes by which carbohydrates are built up. As you have learned, glucose is made in green leaves from carbon dioxide and water. The other carbohydrates are made from glucose. You may now learn that glucose (that is, the sugars having the formula $C_6H_{12}O_6$) is the only carbohydrate the cells of our bodies are able to use. Digestion of sugar and starch is, then, a process of changing these carbohydrates into glucose.

Some of the foods we eat contain considerable glucose. Corn sirup is mostly glucose. This simplest sugar needs no digestion. It passes immediately through the walls of the intestine and directly into the blood stream. It may go directly to the cells where it is used. You will recall that sucrose (cane sugar) and starch are made in the plant from glucose. In the process of digestion as it goes on in your body, sucrose and starch are changed again into glucose.

Glucose is not changed by digestion

The digestion of sucrose is a simple chemical change. A molecule of sucrose and a molecule of water form two molecules of glucose. The equation will help you to understand the nature of this change.

$$C_{12}H_{22}O_{11} + H_2O \longrightarrow C_6H_{12}O_6 + C_6H_{12}O_6$$
$$\text{sucrose} + \text{water} \longrightarrow \text{glucose} + \text{glucose}$$

Does this equation look at all like one you have seen before? The chemical change in digestion of sucrose is the reverse of the chemical change in which sucrose is formed from glucose. A special substance called an enzyme, which is present in the small intestine, causes this chemical change.

It seems necessary to insert here a statement about enzymes. Several different kinds of enzymes play a part in the process of digestion. No one knows exactly what an enzyme is, but we do know very definitely what certain enzymes will do. For example, we know that sucrose is changed in the intestine to glucose. Something there causes this chemical change. This something is an enzyme. There are glands (see Fig. 253) distributed along the digestive system from the mouth through the small intestine. These glands secrete liquids containing enzymes. There are the salivary glands (three pairs) which secrete saliva into the mouth. Gastric glands in the walls of the stomach secrete gastric juice. The pancreas, shown in Fig. 253, secretes pancreatic juice. The liver secretes bile. Glands in the

Enzymes play a part in digestion of foods

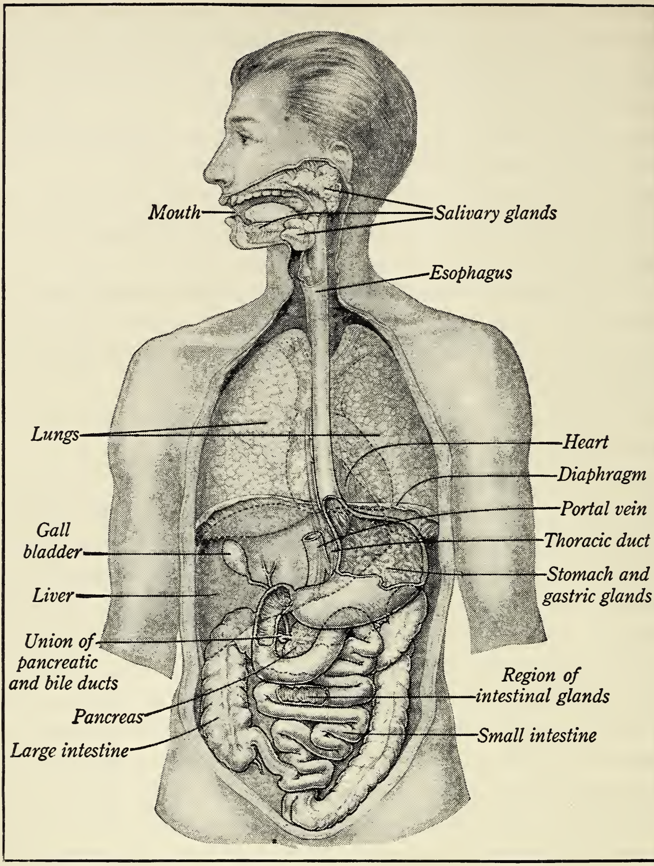


Fig. 253. Many Organs in the Human Body play an Important Part in the Digestion of Food

As you read about the processes of digestion, trace them in this diagram

walls of the intestines secrete intestinal juices. Fig. 253 shows the location of these glands. Each of these secretions (except the bile) contains one or more enzymes. Several different enzymes play a part in the digestion of carbo-

hydrates. There are several that act on proteins. There is at least one that acts on fats. These are extremely important, for without them we should have to feed entirely on food which could be immediately absorbed into the blood stream.

We may return now to the digestion of starch and observe the action of enzymes on it as it moves along from the mouth through the stomach and through the small intestine. Study Fig. 253 as you follow the food along from the mouth to the blood stream.

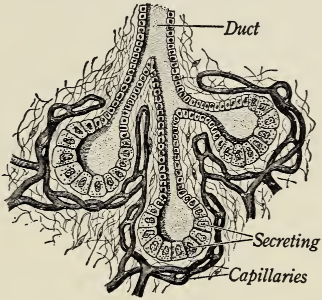


FIG. 254. Various Glands, distributed through the Digestive System, secrete Liquids containing Enzymes

This is a cross section through such a gland

The molecule of starch is, as you have seen, more complex than the molecule of sucrose. By digestion this substance, like sucrose, is changed into glucose. The change from starch to glucose must be thought of as a number of changes that follow one another in succession as the food moves along from the mouth through the stomach and intestine. The succession of changes is caused by enzymes.

Digestion of starch begins in the mouth. An enzyme in the saliva, called ptyalin, starts the process. If we chewed our food long enough, all the starch would be changed in the mouth into glucose. You may recognize the effect of this enzyme if you will chew some food that is mostly starch (a soda cracker, for example) and hold the material in your mouth for as long as a minute or two. You will find that the cracker begins to taste sweet. Ordinarily we swallow food so quickly that there is not time for this enzyme to do all its work.

None of the enzymes secreted in the stomach have any noticeable effect on carbohydrates. In the intestine the digestion of carbohydrates is continued. There are enzymes in the pancreatic juice that digest carbohydrates. See in Fig. 253 where the pancreas is located. Notice the location of the duct through which pancreatic juice flows into the intestine. There are still other enzymes to finish the process, in the juices secreted from the walls of the small intestine. The digestive system is well equipped to digest carbohydrates.

The end product of digestion of carbohydrates is some form of glucose. As glucose is formed, it passes through the walls of the intestine and into the blood. It enters the blood through the portal vein and passes directly to the liver. Notice the location of the liver in Fig. 253.

The blood contains always about the same amount of glucose

There are many fine adjustments necessary for the proper functioning of the body. For example, there must not be much more than one part of glucose to one thousand parts of blood in the body at any one time. If there is more than this, the extra passes out through the kidneys and is excreted as waste. During the digestion of a meal, which continued over a period of two to three hours, glucose is entering the blood in relatively large amounts. Then during the interval to the next meal there is none. The cells of the body function continually, so there must be some way to supply glucose to the cells as it is needed. This brings to attention one important function of the liver. Glucose is carried from the intestine through the portal vein to the liver. In this organ the part which is not needed is removed from the blood and stored. For storage, glucose is changed to a carbohydrate called glycogen. From this storehouse of carbohydrate in the liver, glucose is released to the body as needed. The cells of the liver as seen through a microscope are shown in Fig. 255.

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FIG. 255. The Liver is a Storehouse of Carbohydrates

This photograph shows the structure of the liver as it appears through a microscope

You will recall that energy from solar radiation is stored in molecules of glucose as these are formed in the green leaves of plants. As a result of many changes operating through what seem to be beautifully regulated organisms (the plant and your body), this energy is finally delivered to the cells of your body. The energy is released in your cells when molecules of glucose enter into chemical action with oxygen. Glucose is carried to the cells from the liver. Oxygen is carried to the cells from the lungs. The chemical change which takes place results in the formation of carbon dioxide and water. These, you will note, are the same substances from which glucose was made. The important thing in all this is that this cycle of changes carries a continuous supply of energy from solar radiation to the cells of our bodies.

A cycle of changes carries a continuous supply of solar energy to the cells

B. What is the Origin of Fats and How are Fats prepared by Digestion for Use in the Cells?

Fats, like carbohydrates, may be distinguished by their chemical composition. In fact the chemical composition determines the function which they serve as food. What are *fats*? When you speak of fat meat you use the word to distinguish between fat and lean. Lean meat is muscle tissue. The farmer and the butcher know that lard is made from fat pork. The chemist recognizes lard as a fat. In the process of making lard, fat is separated from the animal cells in which it has been stored. Fat may be melted down from beef and mutton in the same manner. Fat from these sources is called tallow. It is similar to lard in chemical properties. Butter is another kind of fat. The cream that rises to the top when milk is left to stand is butter fat. It is similar to lard and tallow, but, as you well know, it is not the same.

All fats are similar in chemical composition

Other fats are derived from plants. Those from this source are frequently called oils. Olive oil and other oils used for salad dressing are similar to butter and lard in chemical properties. They are similar also in the function they serve as foods in the body. These vegetable oils are really vegetable fats. Whale oil also is a form of fat.

You should recognize the difference between vegetable oils (which we shall call fats) and mineral oils. Mineral oils are derived from petroleum and are used chiefly for lubrication of machinery. A highly refined form of mineral oil is sometimes used for medicinal purposes. But neither this nor any other mineral oil has any value as food, if for no other reason than that it does not pass through the walls of the intestine and into the blood.

Vegetable oils are fats

What is the origin of fats? You have learned that carbohydrates are made from carbon dioxide and water.

Fats are not made directly from these simple substances. They are made from carbohydrates. They may be made in the cells of both plants and animals.

Like carbohydrates, fats are composed of but three chemical elements — carbon, hydrogen, and oxygen. Fats are of different kinds because the molecules of different fats contain these elements in different proportions. Butter and lard and similar substances are really mixtures of several fats. The molecule of a fat is more complex than the molecule of a simple sugar. The formula for the fat of which beef tallow is chiefly composed is $C_3H_5(C_{18}H_{35}O_2)_3$. Outside the parenthesis there are 3 atoms of carbon and 5 atoms of hydrogen. To count the number of atoms shown within the parenthesis you must multiply each of the numbers there by three. Thus there are 54 atoms of carbon ($3 \times 18 = 54$). Similarly there are 105 atoms of hydrogen ($3 \times 35 = 105$) and 6 atoms of oxygen ($3 \times 2 = 6$). Now if you add these to the atoms outside the parenthesis you find that the total number of atoms in this molecule of fat is 173. The fat of which lard is chiefly composed has the formula $C_3H_5(C_{16}H_{31}O_2)_3$. One of the fats found in butter has the formula $C_3H_5(C_4H_7O_2)_3$. These complex formulas show that fats from different sources do not have the same composition.

You may see that a molecule of fat contains a smaller percentage of oxygen atoms than a molecule of a carbohydrate. In the complex molecule of fat of which beef tallow is chiefly composed, there are but 6 atoms of oxygen in a total of 173 atoms. Thus oxygen atoms make up but 3.4 per cent of the total. In a molecule of glucose there are 6 atoms of carbon, 12 of hydrogen, and 6 of oxygen, or a total of 24. Of these, 6 atoms, or 25 per cent, are oxygen. When we recognize the difference in the percentage of oxygen in molecules of fat and of carbohydrates we may explain why these two substances do not have the same food value.

Both fats and carbohydrates are used in a cell for food. Energy is released to the cells as the elements of which the foods are composed combine with oxygen to form carbon dioxide and water. The one which has the smaller percentage of oxygen is the one which will use the larger amount of oxygen in forming carbon dioxide and water. This one will, therefore, release the larger amount of energy. Careful studies have shown that one pound of butter will release 3605 kilogram calories. One pound of sugar will release but 1860 kilogram calories, only little more than half as much. Fats are best for energy. Men who do hard physical labor should eat more fat than men who do office work.

The percentage of oxygen in fats is less than the percentage of oxygen in sugar

Normally, all of us eat considerable fat. None of the fats will pass through the walls of the intestine and into the blood until they are digested. The process of digesting fats is therefore a process of changing them to substances that will pass through the walls.

You may observe that fats will not dissolve in water. Suppose you mix some vegetable fat (olive oil, for example) with warm water and shake it vigorously. In this manner the fat may be broken up into tiny balls; but after you stop shaking the liquid, these balls quickly rise to the surface. If you use water that is warm enough to melt butter or lard and shake either of these fats in the same manner, they too will rise and float on the surface. This shows that fat is not soluble in water.

The digestion of a molecule of fat is a chemical change in which the molecule seems to be split in two parts. The so-called fat-splitting enzyme which causes the chemical change is called lipase. It is contained in the pancreatic juice. Bile from the liver also plays an essential part in the digestion of fats. Bile and pancreatic juice enter the intestine through the same opening, as shown in Fig. 253. After these secretions are mixed, lipase causes the fats to change into soluble substances. These soluble substances pass

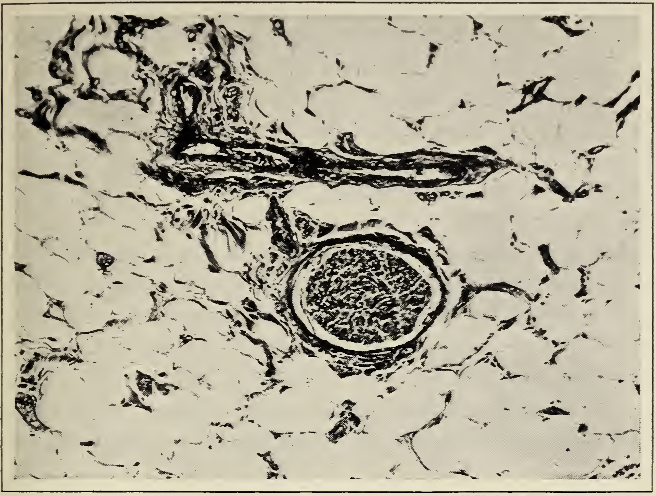

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Fig. 256. Fat is stored in Cells

The round, dark section shown in the center of the photograph is a nerve. The longer dark section above it is an artery. The white matter surrounding these is the fat stored in cells. Can you see any cell walls?

through the walls of the intestine. As soon as these products of digestion have passed through the walls of the intestine, they meet conditions which cause the fats to form again. The chemical change in re-forming the fats is just the opposite of the chemical change in digestion.

Most of the fat passes from the walls of the intestines into the circulation through the thoracic duct. Find the thoracic duct in Fig. 253. Some, however, passes through the portal vein and the liver just as the carbohydrates do.

There are several kinds of fats in every meal we eat. In the digestion of these fats each one produces glycerin, and glycerin from all fats is alike. Each fat will also produce one fatty acid and possibly two or three. The fatty acids from different fats are not alike. The acids are all mixed together, and the glycerin may combine with some other kind of acid

than the kind with which it was combined before digestion. Some of the fats formed after digestion are therefore unlike the fats contained in the food when it was eaten.

After eating fat there is, of course, an increase of fat in the blood. If blood is drawn from an animal after it has eaten a meal rich in fat and if the blood is kept in such a way that it does not thicken, the fat will rise to the surface as cream rises on milk.

Healthy animals (including people) that have been well fed have a good deal of fat stored in their bodies. Cells in which fat is stored are shown in Fig. 256. Stored fats are especially useful to animals that run wild through the winter. Rabbits and squirrels and other animals that look out for themselves in winter find plenty of food during the months of autumn. By the end of November they are usually very fat. As winter approaches, food becomes scarce. Often they are unable to find enough to meet their needs. During this emergency they draw upon the fat stored in their bodies. In this way they are able to live through the winter. By the time spring has come these animals are usually thin and bony.

A well-fed animal stores fat

C. What is the Origin of Proteins and How are Proteins prepared by Digestion for Use in the Cells?

In a sense, the proteins are more important than the other energy foods. We cannot live without them. We could live at least for a time without either carbohydrates or fats. Carbohydrates and fats supply energy, but they alone do not supply all the elements essential for building protoplasm. It is in this sense that proteins are most important. We get our supply of proteins chiefly from lean meat, eggs, milk, cereals, peas, and beans. The proteins from each of these sources are unlike the proteins from each other source.

Proteins are essential for building protoplasm

Chemists have found that proteins are extremely com-

plex substances, but like fats and carbohydrates they are broken up into simpler substances by digestion. The proteins are composed of substances called amino acids. These act as units in the chemical changes in digestion and in building protoplasm. Amino acids are chemical compounds. Like carbohydrates and fats, they contain carbon, hydrogen, and oxygen in their molecules. In addition they contain nitrogen and other elements, especially sulfur, phosphorus, and sometimes iron and some others. There are at least twenty amino acids, and a great number of proteins may be formed from them. It is a little like the number of words that may be formed from the letters of the alphabet. There are only twenty-six letters, but there seems to be no practical limit to the number of words we may build from them.

Proteins are formed from amino acids

Amino acids are formed in the green cells of plants. The manner in which they are formed is unknown, but the carbon, hydrogen, and oxygen in the molecules certainly come from carbon dioxide and water. Nitrogen and the other elements of which they are composed come through the roots from the soil. Again you see that animals depend upon plants. The building blocks (amino acids) essential to the protoplasm in the cells of our bodies are made only in the cells of green plants.

Different kinds of plants form different kinds of proteins, but in all cases the units of which the proteins are composed are amino acids. The proteins in a grain of wheat, for example, are different from the proteins in a grain of corn. Each of these is different from the proteins in peas, beans, or nuts. Similarly, the proteins in the cells of an animal are unlike the proteins from any other source.

Did you ever make dough from wheat flour? The flour is composed mostly of protein and starch. If you work flour and water with your hands or with a dough mixer, you find that it soon works into a sticky mass. The sticky stuff is

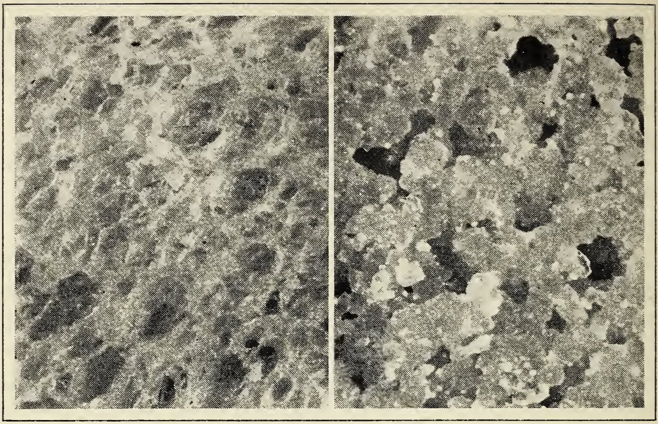

Fig. 257. These Photographs show Magnified Sections of Wheat Bread (to the left) and Corn Bread (to the right)

What difference do you see? Can you explain it?

protein. It is called gluten. If you allow water to run over the dough as you work it, the water will carry the starch away. In this way you can obtain a mass of nearly pure gluten. If you should try to make dough from corn meal you would not have the same success. The protein in corn meal (called zein) will not form this sticky mass. Therefore you cannot make "light" bread (raised bread) from corn meal. Perhaps Fig. 257 will help to explain this.

The chemist has found that gluten is made up of at least sixteen different amino acids. He has found that one amino acid makes up about 45 per cent of gluten. Some of the remaining fifteen are present in extremely small amounts. Albumin from milk contains the same sixteen amino acids and one more that is not present in gluten. The percentages in which these acids are present in these two proteins differ greatly. The acid that composes nearly 45 per cent of gluten composes less than 13 per cent of milk albumin. It is in such manner that proteins differ from each other.

Just as proteins are built up in plants from amino acids, so proteins are broken up by digestion into these same amino acids. A secretion from glands in the walls of the stomach contains an enzyme called pepsin. This starts the process of digesting proteins. A secretion which enters the intestine from the pancreas carries another enzyme called trypsin. Under the influence of trypsin, the process of splitting proteins into amino acids is continued. A third enzyme called erepsin, secreted by glands in the walls of the intestine, also contributes to the same process. The end products of the digestion of protein are a mixture of some twenty amino acids. The acids are soluble in the digestive fluids and pass through the walls of the intestine to the blood. The digested proteins enter the circulation through the portal vein. Like the carbohydrates, they pass through the liver as they move toward the heart.

Amino acids are formed from proteins by digestion

From the heart these acids are carried by the blood to the various cells of the body. In the cells they are built up again into proteins and become a part of protoplasm. Like carbohydrates and fats, the proteins are completely destroyed by the life processes that go on within the cells. The waste products from the use of proteins in the cells are simple substances like those taken from the physical environment and used by the plant to make amino acids. This succession of changes requires a continuous flow to the living cells of both plants and animals of the materials necessary for building protoplasm.

The proteins formed in human cells are unlike, at least in some respects, the proteins formed in the cells of any other animal. A dog or a man may eat bread, meat, eggs, and milk. In both the dog and the man, the proteins are broken up by digestion into the same amino acids. In both, the amino acids that pass through the walls of the intestine are the same. In one case these building blocks

Proteins of one organism are unlike the proteins of another organism

are built into dog tissue. In the other they are built into human tissue. One of the chief differences between dog tissue and human tissue is in the proteins of which each is composed. The proteins in both may be built from the same amino acids, but the amino acids are joined together in different proportions. Even among the same kind of organisms, no two are exactly alike. No two people are exactly alike. No dog is exactly like another dog. One reason why people are not alike is that there are slight differences in the kinds of proteins contained in their cells.

In this study of the manner in which proteins become a part of living cells, it may be helpful to recognize in review five different steps:

1. Amino acids are formed in green cells of plants from chemical elements that come out of the physical environment. There are at least twenty amino acids.
2. Proteins of many kinds are formed from amino acids in the cells of plants. Proteins are stored in plants, especially in seeds.
3. By digestion, proteins are broken up into amino acids.
4. In animal cells, proteins are reconstructed from these amino acids.
5. The protein from animal cells may be food for another animal (as when we eat meat). In this case the animal proteins are broken up into amino acids by digestion, and these are again built into proteins in the cells of the second animal.

D. What happens to the Foods we Eat?

For your lunch at noon let us suppose you ate bread, butter, beef, potatoes, spinach, and fruit with sugar. You used also some salt and some water. What happens to the foods after they are taken into your body? Before answering this question we must learn, first, of what these foods are composed. Study Fig. 258.

Bread is composed mostly of starch. It also contains some protein and a small amount of fat. Butter is mostly

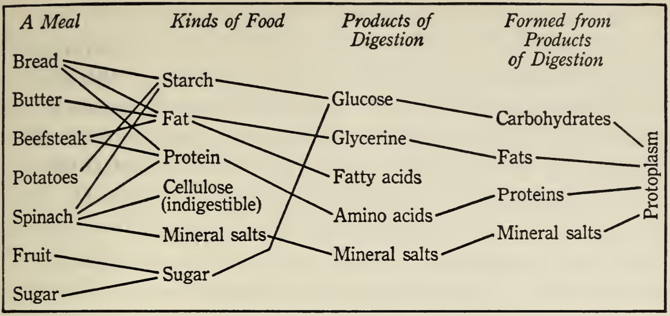

FIG. 258. The Processes of Digestion change Familiar Food Substances into Protoplasm

The diagram indicates the changes which take place in digestion. Substances necessary to protoplasm, but not affected by digestion, are not shown

A meal contains many kinds of proteins, carbohydrates, and fats

fat. Lean meat is mostly protein, but it contains some fat. Potatoes are mostly starch. Spinach contains some starch, a small amount of protein, a little fat, some mineral salts, and a considerable amount of cellulose. Cell walls in plants are composed of cellulose. The fruit probably contains some glucose and possibly a small amount of protein and cellulose. Cane or beet sugar is nearly pure sucrose. This meal will also supply plenty of vitamins. But since we know nothing as yet of the effects of digestion on vitamins, we shall not consider them here.

From this study of the meal we see that it is composed of carbohydrates, fats, and proteins, together with salt and water. Let us analyze it a little further. There are several kinds of carbohydrates in this meal, including starch, cellulose, cane sugar, and glucose. The meal contains butter fat, beef fat, and vegetable fat. There are certainly several kinds of proteins, for the protein in each of the foods mentioned is unlike the proteins in any other one. What happens to these substances after they are taken into the body?

It is easy to understand what happens to the water. It

is taken into the stomach, and it passes almost immediately into the intestine. It then passes directly through the walls of the intestine. In the course of a very few minutes it is part of the blood. The salt you used passes along with the water and is soon in the blood stream. Neither of these is changed in any way by the process of digestion. Of the carbohydrates, glucose likewise needs no digestion. Both the cane sugar and the milk sugar are changed by digestion into forms of glucose. Starch goes through considerable change, but in the end it too becomes glucose. Cellulose is indigestible. Notice, however, that the other carbohydrates are either already in the form of glucose, or are changed to glucose by the process of digestion. This, as you learned, is the only form in which carbohydrates can be used by the cells of the body.

By digestion a meal is changed to a few simple substances

The fats too are dissolved in the digestive fluids and pass through the intestinal walls. It is difficult to estimate the number of different kinds of proteins in the meal, but the number is certainly very large. Yet all of them are made up of not more than twenty or possibly twenty-one amino acids. In the process of digestion they are broken up into these simpler units. Thus as a result of digestion the meal has become glucose, a few different kinds of fats, and a few amino acids. The indigestible remainder, which is chiefly cellulose, passes along through the intestine and is finally thrown off by the body as waste. The digested food becomes part of the blood and is carried by the blood to the cells.

Protoplasm is made from the products of digestion

It is from these products of digestion that living protoplasm is formed. Within each healthy cell there are glucose, fats, and proteins. Protoplasm is a mixture of these substances together with water and mineral salts. The cell is continually using oxygen and releasing energy. Energy is released from the union of oxygen with the chemical elements in any one of these three forms of food.

Protoplasm in the living cells is, of course, continually changing. The food materials of which it is composed are continually combining with oxygen and releasing energy. Waste products are formed and carried away. In order that a cell may continue to live, fresh supplies of glucose, fats, and amino acids must be fed to it in a continuous stream. This continuous stream is the blood. The foods we eat furnish the materials that are carried in it.

In this study of foods we have a partial answer to the question "What is life?" An essential part of life is the process of forming protoplasm and using it for growth and repair and for the release of energy.

All living organisms are made up of cells. These cells secure the materials for growth from food. There are many different kinds of food. All these must be prepared for use in the cells through the processes of digestion. In these processes the foods are broken up into simpler substances and finally pass into the cells as a solution in the blood. In the cells the soluble foods are used to form protoplasm

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Can You Answer these Questions?

1. Why is water important to life?

2. What are six distinctly different types of food?

3. Which of these must be changed by digestion before they reach the cells? Which of them are already soluble when taken into the body?

4. What are some familiar forms of carbohydrates? How do they differ in chemical composition?

5. How are molecules of glucose formed? molecules of sucrose? of starch?

6. What is the value of cellulose in the digestion of food?

7. How does glucose reach the cells of the body?

8. What are enzymes, and what part do they play in the digestion of foods? Why does a soda cracker begin to taste sweet after you have chewed it for a time?

9. What part does the liver play in supplying glucose to the cells?

10. What is one important difference between a fat and a carbohydrate?

11. Why does a fat release more energy in the body than a carbohydrate?

12. How are fats prepared for use by the body?

13. Why are proteins important to life?

14. What are amino acids? What is their relationship to the proteins?

15. What are the steps by which proteins become a part of living cells?

16. Can you trace the way in which your last meal became a part of the living cells in your body?

a. Compare the changes that take place in the digestion of starch with the changes that take place in forming starch from glucose. What is glycogen?

b. Compare the changes that take place in the digestion of fats with the changes that take place when fats are re-formed from the products of digestion.

c. Compare the changes that take place in the digestion of proteins with the changes that take place when proteins are formed from the products of digestion.

Questions for Discussion

1. How many examples can you give from this chapter to illustrate nice adjustment between various parts of the body?

2. The word *digestion* comes from two Latin words meaning "to carry apart." Do you think this is a good definition of the process which takes place?

3. Of which type of food substance — proteins, carbohydrates, or fats — is there the greatest number of different kinds? Support your answer.

4. Arrange the following in the order of what you consider their importance for life, placing the most important one first.

Consider that the one which is most important is the one that would cause death in the shortest time if an animal were deprived of it.

carbohydrates	fats	mineral salts	oxygen
proteins	water	vitamins	

5. If you were trying to reduce the amount of protein in your diet, what foods would you eat less of or in smaller quantities?

Here are Some Things You May Want to Do

1. Make a list of the things you eat during one day. Are your meals well balanced? From which of the things you ate did you get most carbohydrates? most fats? most proteins?

2. Add a few drops of iodine to a glass of water. Smear a little of this water upon a slice of potato or bit of bread. Notice that iodine turns starch blue. Does your experiment suggest anything about the composition of potatoes or bread?

Chapter XXIII · How does the Body function Normally? How is it influenced by the Effects of Alcohol, Tobacco, and the Drugs used in Medicines?

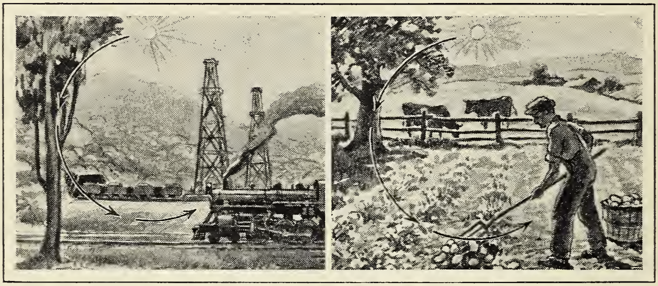

FIG. 259. **Do you think it is Correct to compare the Human Body with a Steam Engine?**

What similarities are there? What are the differences?

The human body is frequently compared with a steam engine. Study Fig. 259. This comparison may be used only in a very limited way. The body and the engine are alike in that both change chemical energy into energy of motion. The body uses energy from foods. The engine uses energy from fuels. As the food or fuel is used, more must be supplied if the body or the engine is to continue to function. Beyond this the two are very different. The engine must be cared for and controlled by intelligence from outside itself. The human body is controlled in part automatically, and in part by intelligence that exists within itself.

Food serves at least three purposes. It is used for energy, for growth, and to rebuild worn or injured cells. Fuel in the engine is of no use except for energy. Machinery does not grow, and worn-out parts cannot be repaired by adding fuel. Worn parts must be replaced.

Our bodies are beautifully adjusted. We see evidences of this adjustment in the manner in which the body works during exercise. In our study in this chapter we shall see first the manner in which a healthy body functions during exercise. Then we shall study the ways in which alcohol, tobacco, and the drugs used in medicines affect its normal working.

A. How does the Body function during Exercise?

Did you ever observe the changes that take place as you begin to take vigorous exercise? Some of the most obvious changes are changes in rate of breathing, rate of heartbeat, amount of perspiration, and color of the skin. Following the period of exercise you have a feeling of fatigue and of thirst. After a short rest you have a feeling of hunger. The changes that take place in the body during the period of exercising are beyond your control.

What is the nature of these changes? We may answer this question by taking observations of ourselves while at rest and then during or immediately following a period of vigorous exercise.

While at rest the average rate of breathing throughout a day for a man of average size is about 16 times a minute. In each minute he takes into the lungs about 20 pints of air, or a little more than 1 pint of air with each breath. Since the air is about $\frac{1}{5}$ oxygen, he takes into the lungs about 4 pints of oxygen in one minute. Of the oxygen entering the lungs about $\frac{1}{4}$ gets into the blood and is carried to the cells. Therefore a man uses about 1 pint of oxygen during one minute while he is at rest. See Fig. 260. This amount of oxygen will produce energy in the form of heat at the rate of about 75 kilogram-calories in an hour. This is at the rate of 1800 kilogram-calories in a day. It is by chemical action of oxygen with food that energy is released. You may recall that 1 kilogram-calorie is enough heat

We are hardly conscious of the breathing process while at rest

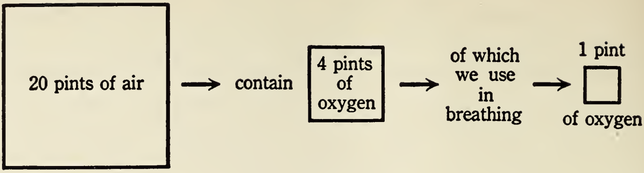

Fig. 260. Only a Small Part of the Air is used in Breathing

to raise the temperature of 1 kilogram of water (about 1 quart) 1° C. Energy of food is measured in these units.

Now count the heartbeat. The heartbeat and the pulse beat are at the same rate. You may find it easier to count the pulse. Place your fingers over your wrist in the manner shown in Fig. 261. Press the fingers firmly against the wrist. If you are in good health you will find that your pulse beats at the rate of about 68 to 75 times a minute.

Fig. 261. The Rate of Heartbeat may be found by Counting the Pulse as shown Here

From your previous study you know that water is leaving the skin by evaporation. Unless the air is very warm, however, you are hardly conscious of the water on your skin, for there is not enough of it to make the skin wet. You know, too, that sugar from your last meal has been stored in the liver and that fat is stored in various parts of the body.

The rate of breathing increases during exercise

Now, for the sake of comparison, make observations of yourself during or immediately following a period of vigorous exercise. Suppose you take part in a quarter-mile run. You are not conscious of

your breathing when the race begins. But after running a short time you become aware that your rate of breathing is very much faster. You soon realize that you are breathing as fast as you can and as deeply as you can. Yet it seems you cannot get enough air to supply your needs.

A runner in your school may do a quarter-of-a-mile run in about one minute (the world's record is a little less than one minute). Possibly we may examine this athlete after his race. Study Fig. 262. You will find that he is now breathing at the rate of about 50 times per minute. This is three times as fast as when he is at rest. He is also breathing much more deeply than before. The volume of air entering his lungs with each breath is now about three times what it was before the race began. His body is using oxygen about ten times as fast as under normal conditions. Thus nearly 10 pints of oxygen may reach his cells in one minute. This will release energy ten times as fast as it was released in this same athlete while he was resting before the race began.

FIG. 262. After a Race a Runner must rest in order that the Bodily Processes may return to Normal

Which of these processes are most affected?

Under the conditions we have observed, the rate at which energy is released through the use of oxygen has increased nearly tenfold. If this rate were continued for one

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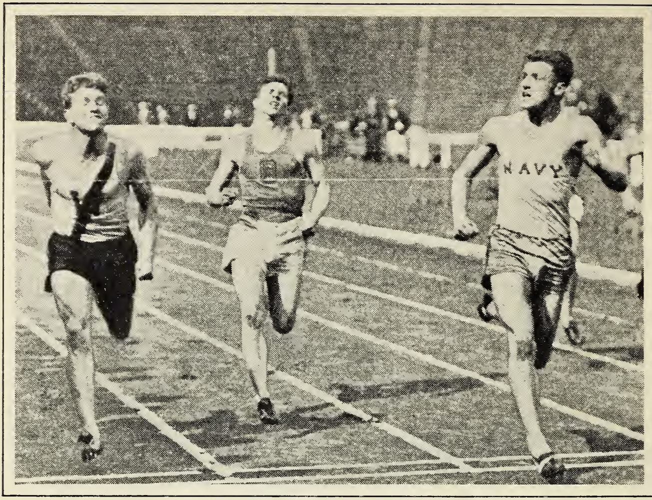

Fig. 263. The Strain which accompanies Vigorous Exercise makes Heavy Demands upon Human Energy

What changes in the bodily processes have taken place during this race?

hour it would release in that interval 750 kilogram-calories. Notice that the racer is panting furiously. You could learn by timing him that his rapid rate of breathing will continue (with lessening intensity, of course) for about twenty or thirty minutes. Obviously the vigorous exercise has made a demand for oxygen which is greater than the lungs can supply, and heavy breathing continues until the need has been met. After racing for one minute the racer is required to use oxygen for twenty minutes at a rate about ten times as fast as he would have used it if he had been resting quietly. Notice the strain pictured on the faces of the runners in Fig. 263.

During a race energy is used much faster than while resting

It is obvious that heat is produced at a more rapid rate when oxygen is used more rapidly. The oxygen entering the blood during the normal rate of breathing releases energy

at the rate of 75 kilogram-calories in an hour. During and following the period of activity it may be at the rate of 750 kilogram-calories in an hour. Under these conditions heat must be released from the body ten times faster than while at rest. But if we could take the body temperature of the athlete we would find that it is about the same as it was before the race, namely, about 98.6° F. What becomes of the rest? We can answer this after a few more observations.

Energy is released as heat

Suppose we now count the rate of heartbeat. After the race the athlete's heart is pounding away at about 140 times a minute, twice as fast as before the race. Besides, it is pounding harder. It is easy to feel the throbbing organ within his chest. Obviously blood is passing through the heart and through the lungs at a faster rate. More oxygen is required in the cells. To meet this requirement the athlete must breathe more deeply and more rapidly to supply the oxygen to the lungs. The blood must move faster in order to carry the increased supply to the cells and in order to carry from the cells the carbon dioxide and other waste products that are formed.

Another observation will show that his skin is pink and that he is covered with perspiration. These are responses of the body which help it to endure the effects of vigorous exercise. They are responses for getting rid of heat. Since heat may be produced ten times as fast during exercise as during rest, it is obvious that it must leave the body ten times as fast. The pink color is evidence that more blood is circulating in the capillaries, or blood tubes, that lie just under the skin. When near the surface the blood loses heat more rapidly by radiation. In this way some of the extra heat is lost.

Heat is controlled in part by perspiration

What function does perspiration serve? You know that evaporation is a cooling process. When 1 quart of water is evaporated, its molecules carry into the air about 500

kilogram-calories. This is the most effective means for regulating the body temperature.

In addition to the need for increased oxygen supply in the cells there is of course a need for an increased food supply. You know that carbohydrates are stored in the liver in the form of glycogen. As carbohydrates are needed for energy they are released to the blood in the form of glucose.

Under normal conditions there is, as you know, about one part by weight of glucose in the blood to every thousand parts of blood. Glucose is used by the active cells. In order to keep up the supply in the blood, therefore, additional quantities must be released to the blood from the liver. There seems to be a fine regulating mechanism here, for glycogen is changed to glucose at a rate which keeps the concentration of glucose in the blood at about one part in a thousand.

There are other fine adjustments. When there is more blood at the surface there is obviously less in the inner part of the body. The spleen, an organ lying near the stomach, is a sort of blood storage tank. The location of the spleen is shown in Fig. 264. Normally it holds about one quart of blood. During vigorous exercise about two thirds of the blood in the spleen is squeezed out. The volume of blood in the liver, in the kidneys, and in the stomach and intestines is less during exercise than at other times. This is one of the reasons why it is best to rest for a while after meals before starting heavy work or vigorous exercise.

The needs of the body determine the rate at which food and oxygen are used

All these things work together. When the need arises, the rate of breathing and the rate of heart action increase. The capillaries near the surface of the skin are enlarged, and more blood flows in them. At the same time blood is forced out of some of the internal organs. Food that has been stored in the liver and in other parts of the body is released and carried by the blood to the active cells. All these processes work together. All of them work in a

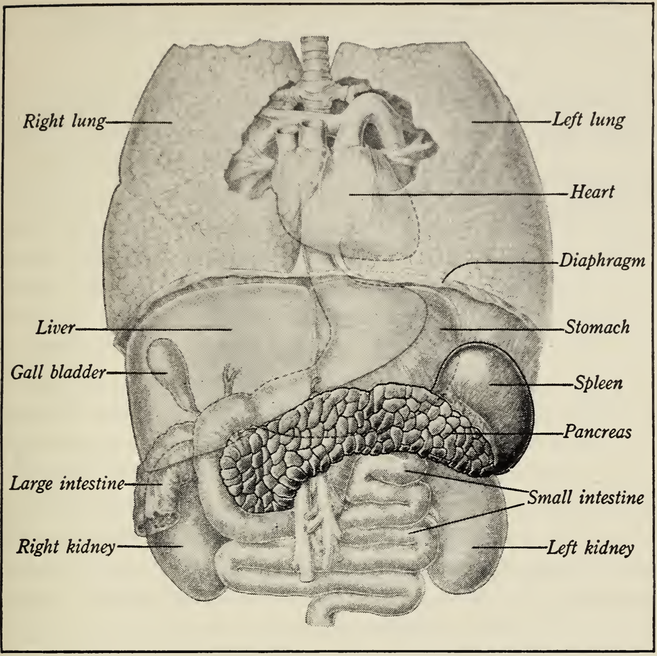

Fig. 264. The Spleen, an Organ Lying near the Stomach, is a Sort of Blood Storage Tank

Does this organ change in size? What causes such a change?

manner that is beyond our control. It seems remarkable that this is so, but life as we know it would be impossible if it were not so. These forces are under the control of the nervous system, but they are not under the control of that part of the nervous system that is concerned with thinking. In all cases of vigorous exercise and heavy work these responses are about the same. In general those responses which are always made in the same manner are made without thinking. They are out of the range of our immediate control. At a later time you may learn more fully about the manner in which these controls are maintained.

B. How do Substances that are not Foods affect the Human Body?

In our study of the human body we are repeatedly reminded that it is a beautifully adjusted organism. All the living cells are bathed continually in a liquid which is mostly water. Oxygen, water, and foods must be taken into the body at regular intervals. The food is used in the cells. The waste products are carried away from the cells, dissolved in water. They are finally excreted from the body. So long as we are in good health the working together of all the cells in the body goes on. Man uses his intelligence to supply good food and water, but under ordinary conditions he is hardly conscious of what goes on inside himself.

Oxygen, water, and foods are needed for normal functioning

The vital processes are in large part chemical processes. Foods are changed into protoplasm, and protoplasm is changed into waste products as energy is released. The body is adapted to use effectively the chemical substances consisting of carbohydrates, proteins, fats, certain mineral salts, water, and air. Other chemical substances taken into the body usually disturb the exactness of the normal functioning. Substances other than foods sometimes taken into the body include alcohol, tobacco smoke, and drugs used as medicines.

In every nation and from earliest times the evil effects of the use of too much alcohol as a beverage have been recognized and measures of control worked out. In recent years several nations have attempted in one way or another to limit the use of alcoholic beverages. The Eighteenth Amendment to the Constitution of the United States, which was in effect from 1920 until 1933, prohibited the manufacture, transportation, and sale of intoxicating liquors. A difficult question arose immediately after this amendment was passed. When is a beverage intoxicating? The Volstead Act, which defined this term, stated that a

beverage was to be classed as intoxicating if it contained more than one half of 1 per cent (0.5 per cent) of alcohol. Soon after Franklin D. Roosevelt became president, before the amendment was repealed, the law was changed in such a way as to consider beer containing 3.2 per cent of alcohol as nonintoxicating. At the time there was much argument as to whether this figure or one slightly larger or smaller should be adopted. Does science give us any exact information which would help to settle this question?

Alcohol affects the normal functioning of the body

Many studies have been made of the effect of alcohol on the human body. The first important conclusion to be drawn from these studies is that there is a wide difference in the way in which different people are affected. Alcohol affects the nervous system. The amount of alcohol in the blood or in the brain can be measured. When the alcohol in the blood reaches one hundredth of 1 per cent, the average person feels that his breathing is freer and he feels a mild tingling of the mucous membranes of the mouth and throat. When the concentration reaches five hundredths of 1 per cent, the average person begins to show some of those signs of unsteadiness which are associated with drunkenness. The person is apt to feel, however, as though he were in the best of form and able to tackle anything or anybody. A person in this stage is apt to be an annoying neighbor in a street car or railroad train. He may act as impulse dictates, failing to observe the standards of social custom. When the concentration reaches one tenth of 1 per cent, the person staggers, talks to himself or sings, and exhibits the various types of behavior associated with drunkenness. The figures above are taken from the researches of Professor Walter R. Miles of Yale University.

The seriousness of this problem does not lie, however, in the annoyance we may be caused by the silly and irresponsible acts of those who are intoxicated. A more serious problem is the relation between the drinker of

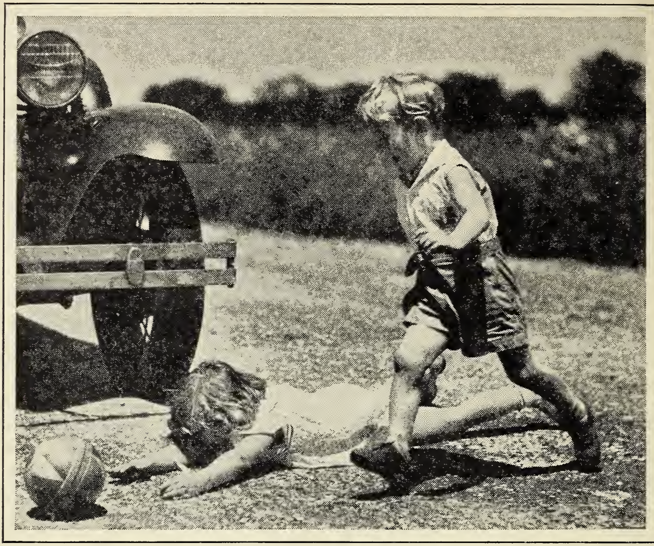

FIG. 265. What do you think might have happened if the Driver of this Car had been under the Influence of Alcohol?

alcohol and the automobile driver. Look at Fig. 265. It takes a certain period of time for a person to act in response to conditions. If you are driving an automobile and are an average person, it takes nearly two tenths of a second for you to start to put on the brakes after your eye sees another car coming toward you or a child start to cross the street in front of you. If you are going 40 miles an hour, your car will travel more than 10 feet before you even start to put on the brakes. It will travel perhaps 120 feet before you can bring it to a complete stop. Now alcohol in the nervous system slows up this response. Scientific tests have shown that a man driving an automobile may be a definite menace owing to the slowing down of the action of his nervous system. The slow response continues for from two to four hours after drinking even moderate amounts of alcohol. The worst of this is that neither he nor anyone

FATAL MOTOR-VEHICLE ACCIDENTS CAUSED BY LIQUOR [1]

Automobile drivers under the influence of liquor are a menace not only to themselves but to passengers, other drivers, and pedestrians.

Year	Total Killed, All Classes	Liquor Cases	Killed in Liquor Cases	Per Cent Killed in Liquor Cases
1922 . .	522	42	49	9.3
1923 . .	578	46	62	10.7
1924 . .	709	43	48	6.7
1925 . .	755	56	63	8.3
1926 . .	705	41	46	6.5
1927 . .	693	40	57	8.3
1928 . .	715	51	51	7.1
1929 . .	777	52	52	6.6
1930 . .	795	76	81	10.1
1931 . .	793	60	68	8.5
1932 . .	768	74	87	11.3
1933 . .	769	64	69	8.9

else can be aware of this change in his nervous system by anything in his own feelings or in his appearance to others. Also people vary so greatly in their response to alcohol that an amount which has little or no effect on one person may very seriously impair the activity of another. Dr. Francis G. Benedict of the Carnegie Institute Nutrition Laboratory says to the automobile driver: "Moderate user, keep off! For at least four hours after a dose of alcohol formerly considered 'permissible,' you, as a motor vehicle operator, may well be considered a 'menace to society.'"

Only a little alcohol makes the driver of an automobile a dangerous person

Figures similar to those in the table above show that more accidents occur in which a drunken driver is concerned than from any other one cause. Some of these accidents are slight, but many result in death or serious injury. Unfortunately it is not always the drunken driver

[1] In addition to these deaths, the Motor Vehicle Department in this large Eastern state estimates that out of a total of 40,943 recorded automobile accidents in 1933 about 4000 were due in one way or another to liquor and that in these 4000 accidents more than 6000 persons were injured. The figures given above are taken from the records of a large Eastern state.

who suffers the consequences. Besides, there is no way of knowing how many accidents have been caused by drivers whose nervous systems contained enough alcohol to cause them to think and act too slowly, but not enough to give any outward sign that they had been drinking.

Not only is the automobile driver affected, but the usefulness of any skilled worker is lowered even by small amounts of alcohol. Repeated experiments have shown this to be true beyond doubt. Tests have been made in such skills as typewriting, marksmanship, and many other types of activity.

Railroad companies will not hire a person for a position in which he is responsible for running trains, if he is known to drink. Too many lives are in the hands of railroad employees. It is not safe to take a chance where human lives are concerned. Professor E. Himwich of the Yale University School of Medicine says that alcohol acts on the nervous system to make a person "less keenly aware of his environment, and his judgment becomes less acute." One interesting thing is that although all these tests show that the worker is less capable and makes more errors, the worker himself usually feels that he is doing quite well, or even better than usual.

Scientists have tried to determine the amount of various liquors a person might take and still not have sufficient alcohol in the nervous system to be considered intoxicated. But owing to the different effects of alcohol on different people and to the many conditions and ways under which liquor is used, these attempts have not been very helpful.

The discussion so far has concerned the moderate drinker. The harmful effects of excessive, that is, too great and continuous, drinking are well known to the medical profession. The destroying of certain tissues, with weakening of the operation of organs such as liver and kidney, are brought about by constant and excessive drinking. On the average the

Excessive use of alcohol is injurious

length of life is definitely shortened by excessive drinking, even if practiced only once in a while.

If this were not a machine age, the alcohol problem would be one of proper use as against abuse. But in our complex civilization keenness and quickness of judgment are needed at every turn in order to handle safely and well the machines which science has put into the hands of men. This being the case, even the moderate use of alcoholic drinks sets a serious problem. In this modern world the bookkeeper who uses calculating machines is apt to make more errors, the man who crosses a crowded street is more likely to land in a hospital, and the man who drives an automobile is more likely to take the life of someone else, if he has increased the alcoholic content of his blood beyond one or two hundredths of 1 per cent.

Alcohol is a narcotic

Alcohol is classed as a narcotic rather than a stimulant. Many people think it is a stimulant because of the flushed face and feeling of warmth which it gives. This is not due to stimulation. It is due to the fact that the blood vessels allow the blood to come to the surface of the skin where the sense organs are. The body is really losing heat. Alcohol should not be used when a stimulant is needed, as in case of fainting, for it produces an effect opposite to the one desired. A stimulant increases bodily activity. A narcotic hinders it and tends to produce unconsciousness. That alcohol is a narcotic when taken in large quantities is evident to anyone. The common "dead drunk" expresses this perfectly. The use of alcohol, like that of other narcotics, may become a habit.

The functioning of the human body under the influence of alcohol is not the same as the normal healthy functioning. An athlete under the influence of alcohol would have a poor chance to win in a quarter-mile race. Besides, such vigorous exercise would produce effects on a runner, under the influence of alcohol, from which he would be slow to recover.

Tobacco also affects the normal functioning of the body. Smoking has the effect of a stimulant, for it causes an increase in the rate of heartbeat. There can be no doubt that excessive smoking is injurious. The most obvious injury is to heart action. It is difficult to say what excessive smoking is, for what may seem to be moderate smoking by one person produces the same effects as what may seem to be excessive smoking by another. In other words, there is a great difference between individuals. Certainly there are some people who are seriously affected by what seems to be moderate smoking. These people should not smoke at all. People who experience dizziness or other unpleasant effects after smoking should discontinue the practice.

Excessive smoking disturbs normal functioning

Growing boys and girls are injured most by tobacco. The injury is to the heart and the nervous system. When you see many people using tobacco, you may think it is not harmful. But there are several things that may truthfully be said against the use of tobacco. There is really nothing that can be said for it. The first-hand observations of athletic coaches and trainers seem to furnish convincing evidence to them that tobacco users do not make good athletes.

What about the use of drugs as medicines? When you go to a physician you expect him to give you something to take, but skillful physicians of today make less use of medicines than did physicians a few years ago. When you are ill, it is because the processes which go on in your body are not functioning normally. The body has the power, at least in some measure, to protect itself from illness. Usually the most effective treatment for illness is rest and protection from exposure.

Drugs used as medicines disturb normal functioning

There are treatments by means of which the power of the body to protect itself may be strengthened. Vaccination increases your protection against smallpox and typhoid

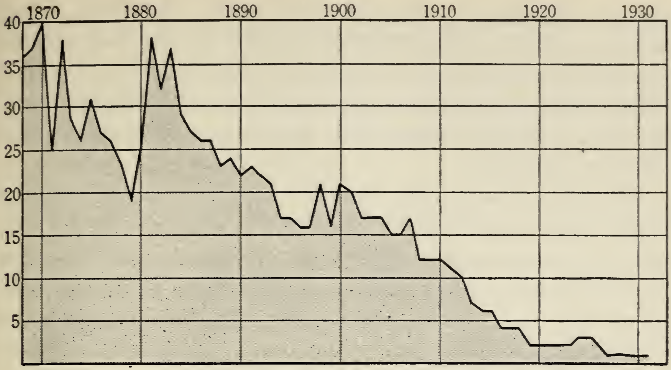

FIG. 266. Vaccination increases One's Protection against Typhoid

This graph shows the number of typhoid cases per thousand inhabitants in a certain city over a period of years. What steps other than vaccination may have helped to lower the rate?

fever. Study the graph in Fig. 266. The toxin-antitoxin treatment strengthens your protection against diphtheria. When a person is ill with diphtheria, antitoxin helps to cure the illness. There are also antitoxins that are effective in the treatment of tetanus and hydrophobia.

There are some drugs that have a definite effect in curing certain diseases, but the number of these is very small. Malaria is a disease caused by a small animal parasite that lives in the blood and destroys the red blood corpuscles, which are small living cells carrying oxygen through the system. Quinine is a poison to these little animals. When it is taken according to a definite schedule it will cure this disease. There are other illnesses that may be cured by treatment of this sort, but for the treatment we must depend upon a skillful physician.

Prescribing medicine for oneself is dangerous. If you feel any effects from a medicine at all, it is probably because it has produced an action on your heart. Frequent use of such medicines is certain to be injurious. It is safest to avoid prescribing any medicine for oneself and to depend

upon your body to correct its own minor ailments. When suffering from a minor ailment avoid fatigue and protect yourself from exposure. The use of drugs is likely to hinder rather than to help the body back to normal functioning. In case of severe illness you must seek the advice of a capable physician.

This brief study of the effects of alcohol, tobacco, and the drugs used in medicines is sufficient to show that these substances are disturbers of the normal functioning that goes on within the enormously complex mass of living cells composing the human body. The only requirements for normal functioning are oxygen, water, and foods. There must be a continuous flow of these essential substances to all the cells. As these are used in the cells, energy is released and waste products are formed. Changes are in progress within the cells during every instant of time, and throughout these changes a beautiful balance is maintained. The evidence of this balance is in the fact that the changes are neither too fast nor too slow. The rate of change is determined by the needs of the body. During vigorous exercise changes go on more rapidly, and during periods of rest they are slower.

We suffer discomfort when the needs of the body are not met. A feeling of suffocation is the call of the body for oxygen. This feeling is experienced during vigorous exercise, or during mild exercise in the thin air of a mountain top. The discomforts of hunger and thirst are the calls of the body for food and water.

Life itself is the result of orderly but enormously complex changes. As a result of these changes there is a continuous flow of energy, having its origin in solar radiation, through the cells of living organisms. In order that this flow of energy may continue, there must be a continuous flow of nonliving matter to the cells in the form of foods. There must also be a continuous flow of nonliving matter from the cells in the form of waste products. If we as individuals

are to live in health and comfort, we must supply our cells with good food. In addition we must avoid taking into our bodies substances that are not foods. It is the presence of these substances within the body that disturbs the beautifully balanced functioning which we recognize as a sign of vigorous and joyful living.

Under normal conditions the human organism functions almost automatically and needs but little attention. Certain substances, such as alcohol, tobacco, and drugs used except under doctor's orders, disturb this normal functioning.

Can You Answer these Questions?

1. In what important sense is it incorrect to compare the processes of the human body with those of a steam engine?

2. What are three things that food does for us?

3. What are some of the bodily changes that take place as the result of vigorous exercise? Consider breathing, pulse, and perspiration.

4. Why does one breathe more quickly during and immediately after vigorous exercise?

5. What is meant by the statement that "the vital processes are, in large part, chemical processes"?

6. Why have many nations fought the use of alcohol as a beverage?

7. What are some of the effects of alcohol upon the nervous system?

8. In what way does the use of alcohol affect an automobile driver?

9. Is alcohol a stimulant or a narcotic? What evidence can you give to support your answer?

10. Is tobacco a stimulant or a narcotic? Again, what evidence have you?

11. What is the effect of tobacco upon the growing boy or girl?

12. Why are medicines used in some cases of illness?

13. Why is it sometimes dangerous to prescribe medicine for oneself?

Questions for Discussion

1. What arguments should you advance as an answer to the person who argues that the moderate use of alcohol is not injurious?

2. Why is the alcohol problem a more important one in the machine age of today than it was in the civilization of a thousand years ago?

3. Do you think the use of alcohol or tobacco should be prohibited by law?

4. Sometimes you may hear people say of an athlete that he is "burned out." What is meant by this? Do you think it is a good term?

5. Which do you think is the hardest race, a hundred-yard dash, a mile run, or a Marathon? Why?

Here are Some Things You May Want to Do

1. Look through some of the newspapers and magazines that come to your house and see how many advertisements they contain of so-called "remedies" which you think might be harmful. Do any of the radio programs advertise such "remedies"? Why do you think newspapers, magazines, and radio stations accept such advertisements? What can you do to make up for the results of such advertising?

2. During the 1933–1934 session of Congress the so-called "Tugwell Bill" was introduced. It had for its purpose the regulating of the drug industry. See what you can find out about this bill, and why it was so bitterly attacked by certain interests.

3. Many books have been written about fake remedies and the dangers to human life from them. An easy one to read is Kallet and Schlink's *10,000,000 Guinea Pigs*.

4. Count your pulse beat after you have been sitting for some time. Now do the "standing run" for one minute. Count your pulse beat again. Count your breathing rate. Count these again after five minutes and again after ten minutes. Why were the rates faster after exercise?

A SUMMARY VIEW OF THIS CHANGING WORLD

IN ALL OUR OBSERVATIONS on the surface of the earth we see things in the process of change. We see in these changes the effects of energy as it flows over the surface of the earth and through the living cells of plants and animals. Energy comes to the earth in the rays of the sun. The earth turns on its axis, and the sun and the stars seem to shift across the sky. The earth revolves in its orbit, and the position of the vertical rays of the sun shifts back and forth between the tropic of Cancer and the tropic of Capricorn. The curvature of the earth, together with the changes in the position of the vertical rays, causes a continual change in the intensity with which the energy from the sun falls upon different regions.

The shift in position of the vertical and the slanting rays of the sun determines the location of the zones and determines the physical conditions within the zones.

Energy tends to distribute itself uniformly over the earth's surface. It flows from regions where it is most intense to regions where it is least intense. Regions of cold are warmed as energy flows to them. Regions of heat are cooled as energy flows away. Air and water are its principal carriers. Energy is distributed by the wind as it blows over the earth's surface. It is distributed by water as the water evaporates, condenses as rain, and flows again into rivers, lakes, and seas. Over much of the earth the changes from heat to cold and from cold to heat are through the temperature range that causes freezing and thawing. The extremes of heat and cold, of dryness and rainfall or snowfall, and of storm and calm are determined by the distribution of energy from solar radiation.

Energy from this same source flows through the cells of living things and makes life possible. There are some regions of heat and dryness, and there are some regions of cold, in which conditions are so severe that living things can hardly endure. Over most of the earth, however, there are living things adapted to live in the physical conditions that prevail

around them. Plants and animals depend closely upon their physical environment, so closely, in fact, that many organisms cannot live when removed from their natural home.

There are powerful forces with their origins in solar radiation. These, together with the force of gravitation, are wearing down the surface of the earth and moving the earthy materials from higher to lower levels. By the continuous action of these forces high mountains and plains are slowly worn down and low places are filled up. Along with the change in elevation there is a change in physical conditions. Through long eras of geologic time regions of cold may become more temperate, regions of heavy rain may become arid, and arid regions may become more humid. As physical conditions within a region change, the characters of the plants and animals change. Only those organisms that become adapted to the changed conditions can continue. Fossils found in stone show clearly that through geologic time the character of organisms on the surface of the earth has changed enormously.

There is another source of energy that plays a part in changes on and within the earth. It is the energy in the molecules of the hot rock beneath the solid crust. From these molecules comes a force that is acting upward. The force of gravity on the surface of the earth is downward. The two forces tend to balance each other, and each holds the other in check. But the pressure of the earth's crust on the softer material beneath the surface is continually changing as mountains are worn down and carried to the sea. Where the pressure downward becomes less, the forces from within the hot rock beneath cause the surface to rise, forming plains and mountains. The molten rock rises against a surface of less pressure, because rock from regions of greater pressure flows in to force it upward.

Thus we see forces with their origin in the energy of solar radiation, forces with their origin in the energy of hot molecules that make up the plastic material beneath the surface of the earth, and the force of gravitation, all working together

to produce changes on the surface of the earth. As a result of these forces mountains may be raised in one region while in another the surface may be lowered until the sea flows over it.

The action of these forces upon one another has reduced the surface of the earth to the form in which it exists today. In the processes of living, materials from the crust of the earth are built into protoplasm, and marvelous plant and animal organisms are built up of cells containing this living stuff. In man, as in all other organisms, we may recognize continuous change as matter and energy are used in life processes.

Man and other organisms are adapted to live in, and depend upon, the physical conditions produced by the action of these cosmic forces on each other. Life is delicately adjusted to live within the narrow range of these physical conditions. If the average temperature about us in the temperate zone were lowered by only a few degrees, the region would be covered continually with ice and snow. If the temperature were raised only a few degrees, it would be hot enough to destroy present forms of plants and animals.

There are other conditions that show the narrow range within which life now exists. Suppose the mass of the earth were less. The force of gravity would be less, and consequently the atmosphere around us would be less dense. We are adapted to live in an atmosphere exerting a pressure of fifteen pounds per square inch and containing 21 per cent of oxygen. If either of these conditions were very greatly changed, life as we know it could not continue. Suppose fifty hours instead of twenty-four were required for one rotation of the earth. We are adapted to a day of twenty-four hours. We could hardly live through the long cold nights and the long hot periods of sunlight that would accompany this longer day. If the earth's axis were inclined more or less than it is, everything would be different. It is a combination of many known conditions, and possibly many more that are unknown, that make it possible for protoplasm to exist on the

earth as living stuff. It may seem that a slender thread is supporting life on earth, but these physical conditions have existed about as they are now for many millions of years. There is convincing evidence that the sun shone and that water flowed over the surface of the earth back in the Archæozoic era, very much as they do today. Maybe there is satisfaction and stimulation in the thought that physical conditions about us, as we know them today, have lasted for so long. The more we know of life, the more we see it as an exciting and adventurous experience.

Of all the animals, man alone is able to exercise a measure of control over energy and the living things around him. As you continue in your study you may learn how he has used this control to build great industries, to modify the character of plants and animals so that he may use them to meet his needs, and, by means of instruments, to extend his explorations beyond the confines of the earth into the farthermost reaches of the universe. There are great possibilities and distinct limits placed upon the activities of man. Through the exercise of his intellect he is developing his possibilities and gaining increasing control of the factors of his environment. Those who read this book will witness a larger measure of control of the forces of nature than any preceding generation has seen. What will be your part in it?

Readings in Science

BIANCO, M. W. All about Pets. The Macmillan Company, New York, 1929.

Literally "*all* about" mice, rats, dogs, cats, rabbits, guinea pigs, birds, and the aquarium pets. Beautiful pictures.

BRASHER, R. Secrets of the Friendly Woods. D. Appleton-Century Company, Inc., New York, 1926.

Beautiful pictures, by the author, of all the animals described. When you finish this book, you will feel as though you have been watching the habits of animals yourself, instead of through the medium of the book.

BREWSTER, E. T. This Puzzling Planet. The Bobbs-Merrill Company, Indianapolis, 1928.

Excellent reference for volcanoes, earthquakes, and mountain-making; also for theories about the origin of the earth.

BROOKS, C. F. Why the Weather? Harcourt, Brace and Company, New York, 1924.

A splendid, easy, interesting, and accurate account of the weather and its causes.

CHANT, C. A. Our Wonderful Universe. World Book Company, Yonkers-on-Hudson, New York, 1928.

A well-illustrated and readable treatment of elementary astronomy. Its divisions are Part I, "The Celestial Sphere and its Motions"; Part II, "The Sun and its System"; Part III, "The Universe of Stars."

CHAPMAN, FRANK M. Handbook of Birds of Eastern North America. D. Appleton-Century Company, Inc., New York, 1932.

Handbook listing dates of spring and fall migrations; color charts help in identification.

CLARKE, GEORGE AUBOURNE. Clouds. E. P. Dutton & Co., New York, 1919.

The first half of this book treats of the nature and causes of cloud forms, and the second half of the book is devoted entirely to beautiful illustrations of cloud forms.

CURTIS, CARLTON C. A Guide to the Trees. Greenberg, Publisher, Inc., New York, 1925.

A guide to the trees of northeastern North America which uses the leaf as the principal means of identification.

DALY, REGINALD ALDWORTH. Our Mobile Earth. Charles Scribner's Sons, New York, 1926.

Explains earthquakes, volcanoes, and the earth's interior. Illustrations are numerous and excellent.

Davis, M. L. Uncle Sam's Attic. W. A. Wilde Company, Boston, 1930.

An enthusiastic description of the climate, the scenery, and the resources of the Far North.

Duncan, Captain Richard. Air Navigation and Meteorology. The Goodheart-Willcox Company, Inc., Chicago, 1929.

An account of the relations of aviation and weather.

Emerson, Haven. Alcohol and Man. The Macmillan Company, New York, 1930.

An authentic treatment of the effects of alcohol upon man which enables the reader to arrive at the truth about this important matter. It is written for lay readers by doctors.

Fenton, C. L. The World of Fossils. D. Appleton-Century Company, Inc., New York, 1933.

The title explains itself.

Fishbein, Morris. Shattering Health Superstitions. Liveright Publishing Corporation, New York, 1930.

These authoritative discussions regarding health superstitions should challenge junior-high-school pupils. The book upsets many medical superstitions and explodes many false notions and beliefs about health.

Goldring, Winifred. Handbook of Paleontology for Beginners and Amateurs. New York State Museum Bulletin.

Accurate without being technical. Especially good for shell fossils. There are two separate publications: Part I, *The Fossils*, 1929; Part II, *The Formations*, 1931.

Haggard, H. W. The Lame, the Halt and the Blind. Harper & Brothers, New York, 1932.

Vividly relates the changes that have been brought about in living conditions with an increase in medical knowledge.

Hotchkiss, W. O. The Story of a Billion Years. The Williams & Wilkins Company, Baltimore, 1933.

A brief overview of the field of geology, written especially for those who lack a fundamental knowledge of it.

Humphreys, W. J. Weather Proverbs and Paradoxes. The Williams & Wilkins Company, Baltimore, 1923.

An interesting collection of sayings about the weather and a discussion of their relative worth from a scientific standpoint.

Huntington, Ellsworth. The Human Habitat. D. Van Nostrand Company, Inc., New York, 1929.

The earth as a place to live, and why certain peoples are different from others.

HYLANDER, C. J. The Year Round. G. P. Putnam's Sons, New York, 1932.

A book of the out of doors arranged according to the seasons. Detailed descriptions of the "wild life of out of doors," with life histories and some adaptations to environment.

JAEGER, E. C. Denizens of the Desert. Houghton Mifflin Company, Boston, 1922.

Stories of typical species of animals found in the desert.

JEANS, SIR JAMES. The Stars in their Courses. The Macmillan Company, New York, 1931.

A series of radio talks furnished the background for this book. Jeans's most useful book for junior-high-school science.

KALLET, ARTHUR, and SCHLINK, F. J. 100,000,000 Guinea Pigs. The Vanguard Press, New York, 1933.

Here you may see how you and I and every other consumer have sometimes been forced into the rôle of laboratory guinea pigs.

KRANZ, J. C. Fighting Disease with Drugs. The Williams & Wilkins Company, Baltimore, 1931.

This story of pharmacy is written from the pharmacists' point of view and gives clearly their contributions to public health.

LEE, WILLIS T. Stories in Stone. D. Van Nostrand Company, Inc., New York, 1926.

This is a book of proved popularity. It is about the geological changes that have taken place in our country.

LOOMIS, F. B. Field Book of Common Rocks and Minerals. G. P. Putnam's Sons, New York, 1923.

This is perhaps the best field guide for the identification and study of rocks and minerals. It also gives explanations of the conditions under which they were formed.

LUTZ, FRANK E. Field Book of Insects. G. P. Putnam's Sons, New York, 1921.

An excellent field guide to insects. Pupils can readily identify specimens by the drawings and colored plates. The descriptions are good.

MCGILL, JANET. The Garden of the World. Thomas S. Rockwell Co., Chicago, 1930.

A short and interesting survey of the plant world.

MATHER, KIRTLEY F. Old Mother Earth. Harvard University Press, Cambridge, 1929.

A history of our earth as told by a geologist who views organic evolution as a delightful pageant. It has proved to be a very popular scientific book.

MATHER, KIRTLEY F. Sons of the Earth. W. W. Norton & Company, Inc., New York, 1930.

The development of life on the earth through the various geological ages.

MEDSGER, OLIVER P. Nature Rambles — Spring. Frederick Warne & Co., Inc., New York, 1931.

This book and the three books following are beautifully illustrated. Only one who has lived in the woods and observed keenly could write these stories of wild life as this author has done.

MEDSGER, OLIVER P. Nature Rambles — Summer. Frederick Warne & Co., Inc., New York, 1932.

MEDSGER, OLIVER P. Nature Rambles — Autumn. Frederick Warne & Co., Inc., New York, 1932.

MEDSGER, OLIVER P. Nature Rambles — Winter. Frederick Warne & Co., Inc., New York, 1932.

MELLEN, I. Young Folks' Book of Fishes. Dodd, Mead & Company, New York, 1929.

This is an excellent survey of the topic "Fishes." The author's information was obtained at first hand, for she has worked with fish at the New York Aquarium.

MERRIAM, J. C. The Living Past. Charles Scribner's Sons, New York, 1930.

Prehistoric animal and plant life in America. Chapters I and II are about fossil remains, and Chapter V is about the Grand Canyon.

MOSELEY, E. L. Other Worlds. D. Appleton-Century Company, Inc., New York, 1933.

A splendid treatment of our solar system and its origin; a brief discussion of variable, double, and multiple stars; and a picture of the universe.

MOTT-SMITH, M. The Story of Energy. D. Appleton-Century Company, Inc., New York, 1933.

An excellent exposition of energy and energy transformations.

MOULTON, FOREST R. Astronomy. The Macmillan Company, New York, 1932.

Written by one of the foremost astronomers.

NEEDHAM, J. G., and NEEDHAM, P. R. A Guide to the Study of Fresh-Water Biology, with Special Reference to Aquatic Insects and Other Invertebrate Animals. American Viewpoint Society, Inc., New York, 1927.

A condensed set of keys, tables, and pictures to make recognition of fresh-water life easier. Excellent for identification by easily observed external differences.

NININGER, H. H. Our Stone-Pelted Planet. Houghton Mifflin Company, Boston, 1933.

Astronomers gather all their data by the use of light, with one exception — that of the data furnished by meteorites. This book treats the story of meteorites in a comprehensive yet readable manner.

POLAK, JANET. This Physical World. Thomas S. Rockwell Co., Chicago, 1930.

One of the simplest treatments of the various forms of energy with which we are surrounded. It is written especially for the younger readers.

REED, CHESTER A. Bird Guide. Doubleday, Doran and Company, Inc., Garden City, New York, 1909–1910.

This is divided into two pocket-sized guides which can be used easily in the field: Vol. I, *Water Birds, Game Birds, and Birds of Prey*; Vol. II, *Land Birds East of the Rockies*. These are the most useful field guides for birds available.

REED, WILLIAM MAXWELL. The Stars for Sam. Harcourt, Brace and Company, New York, 1931.

About two thirds of this book treats of the solar system. It is easy to read and very interesting.

RIDGLEY, DOUGLAS C., and KOEPPE, CLARENCE E. Fundamentals of Climate. McKnight & McKnight, Bloomington, Illinois, 1932.

A summary of the fundamentals of climate, concise and nontechnical.

ROBINSON, W. W. Beasts of the Tar Pits. The Macmillan Company, New York, 1932.

A vivid picture of the tragedies which befell many Pleistocene animals at the La Brea tar pits of California. The story obtained from this record gives us the succession of life that existed in California during that time.

SHAW, NAPIER. The Drama of Weather. The Macmillan Company, New York, 1933.

Authoritative, beautifully illustrated book on weather.

STETSON, HARLAN T. Man and the Stars. McGraw-Hill Book Company, Inc., New York, 1930.

Gives the reader an appreciation of the contributions of such men as Copernicus, Tycho Brahe, Kepler, Galileo, and others.

TAYLOR, NORMAN. A Guide to the Wild Flowers. Greenberg, Publisher, Inc., 1928.

By a curator of the Brooklyn Botanic Garden. Includes the most prominent wild flowers of northeastern United States. Contains a finding list which is arranged by color and flowering season.

TILTON, GEORGE H. The Fern Lover's Companion. Little, Brown and Company, Boston, 1927.

An attractive handbook whose descriptions and illustrations will readily enable the beginner to identify ferns.

Van Cleef, Eugene. The Story of the Weather. D. Appleton-Century Company, Inc., New York, 1929.

One of the best books for the study of weather.

Van Loon, H. W. Van Loon's Geography. Simon and Schuster, Inc., New York, 1932.

Climate and habitats and geography as you like it.

Walton, George L. The Flower-Finder. J. B. Lippincott Company, Philadelphia, 1930.

Easy to read and easy to use because the flowers are classified according to color. There are large, fine, line drawings of nearly every variety of wild flower, as well as many photographs.

Science Words

KEY TO THE SOUNDS

ă *as in* at	ē *as in* be	ō *as in* go	ŭ *as in* us
ā *as in* ate	ẽ *as in* her	ô *as in* horse	ū *as in* use
ȧ *as in* ask	ẹ *as in* vowel	ọ *as in* connect	ụ *as in* circus
ä *as in* arm	ĭ *as in* bit	oi *as in* oil	tū *as in* nature
ạ *as in* sofa	ī *as in* bite	o͞o *as in* food	ŋ *as in* ink
ĕ *as in* bet	ŏ *as in* got	ou *as in* out	

absolute humidity (ăb′so lūt hū mĭd′ĭ tĭ). The weight of water vapor in a given volume of air (p. 174)[1]

adaptation (ăd ăp tā′shụn). Change of the structure or behavior of a plant or animal which makes it suited to the environment in which it lives (p. 147)

adequate (ăd′ē kwāt). Sufficient; enough (p. 388)

Agassiz (ăg′ạ sē), **Louis John Rudolph.** A famous Swiss scientist (1807–1873) (p. 343)

algæ (ăl′jē) (*sing.* **alga** (ăl′gạ)). The lowest group of green plants. They have no definite root, stem, or leaf and usually live in water. Seaweeds and the various pond scums are algæ (p. 472)

allosaurus (ăl ō sô′rụs). A flesh-eating dinosaur (p. 407)

almanac (ôl′mạ năk). A calendar of months and days, often giving many facts about the weather, astronomy, etc. (p. 111)

amino (ăm′ĭ nō) **acids.** The acids from which proteins are formed (p. 497)

ammonium (ạ mō′nĭ ụm) **compounds.** Certain compounds containing nitrogen and hydrogen combined with other elements. Familiar compounds are ammonium chloride, NH_4Cl, and ammonium carbonate, $(NH_4)_2CO_3$ (p. 476)

Amœba (ạ mē′bạ). A one-celled jellylike animal which has no definite shape and moves about as the protoplasm within it flows from one place to another (p. 473)

amphibian (ăm fĭb′ĭ ạn). One of a class of animals which usually live first in water, as tadpoles, then on land. The amphibians have moist, smooth skins (p. 234)

aneroid (ăn′ẽr oid) **barometer.** A barometer whose action depends upon the varying pressure of the atmosphere on the top of an elastic metal box (p. 166)

annual. A plant which lives only one year (p. 227)

annual rings. Alternating dark and light bands, seen on the stump of a tree which has been cut down. They are caused by changes in rate of growth of a tree as seasonal conditions change (p. 383)

anthracite. The highest grade of coal; hard coal, differing from soft coal in consisting of almost pure carbon (p. 386)

[1] References are to pages in the text where the words first occurred.

anticlines (ăn′tĭ klīnz). The crests or upfolds of folded rocks (p. 368)
anticyclone (ăn′tĭ sī′klōn). Winds rotating about a center of high atmospheric pressure (p. 185)
anti-trade winds. Winds which arise at the equator when the trade winds from the north and the south meet, forcing the warm less-dense air at the equator upward. This air then spreads outward toward the poles and forms the anti-trade winds (p. 121)
archæologist (är kē ŏl′ō jĭst). One who studies the remains of early races of man (p. 353)
Archeozoic (är kē ō zō′ĭk). The oldest of the five great eras into which geologists divide the earth's history (p. 326)
arctic tern. A sea bird related to a sea gull, and one of the greatest travelers known. It is smaller and slimmer than a gull, with long wings and gray-white plumage (p. 247)
Aristotle (ăr′ĭs tŏt ′l). A great Greek thinker and student (384–322 B.C.). For a long time his word was accepted as authority in scientific matters (p. 469)
atom (ăt′ŭm). The smallest part of a chemical element. Atoms combine to form molecules. According to the electron theory atoms are composed of electrons and protons (p. 332)

bacterium (băk tē′rĭ ŭm) (*pl.* **bacteria**). A plant so small that it can be seen only through a microscope. Some bacteria are harmful to man, but many others are useful (p. 303)
barnacles (bär′nạ k′lz). Small sea animals which are found adhering in groups or clusters to rocks or to the bottoms of ships etc. They have white shells (p. 277)
barograph (băr′ō gráf). An instrument which automatically records atmospheric pressure (p. 170)
barometer. An instrument used to measure air pressure (p. 163)
barrier (băr′ĭ ẽr). Anything which obstructs, hinders, or confines (p. 394)
basaltic (bạ sôl′tĭk). Of the nature of basalt. Basalt is a fine-grained, dark-colored rock which has been formed by heat (p. 360)
belt of calms. An irregular section of the earth, in the torrid zone, which shifts several degrees north or south with the changing seasons. It is marked by calms, as the air movements are mostly upward (p. 133)
Betelgeuse (bĕt ẹl gẽz′). A large red star in the constellation of Orion (p. 447)
biennial. A plant which lives during a part of two growing seasons. Such plants often store food in fleshy roots or stems the first season, and produce seed and die the second season (p. 227)
biology (bī ŏl′ō jĭ). The science of living organisms (p. 343)
bluebonnet. A plant of the pea family. It bears a handsome cluster of purplish-blue flowers. The state flower of Texas (p. 259)
botanical (bō tăn′ĭ kạl). Having to do with the study of plants (p. 221)
botanical garden. A place where plants are grown and placed on exhibition (p. 385)
botanist (bŏt′ạ nĭst). One who studies botany (p. 225)
botany. The science concerned with the study of plants (p. 221)

bowlder (bōl′dẽr). A large rock, with rounded edges, that stands out prominently from the other rocks around it (p. 319)
bromine (brō′mĭn). A nonmetallic element. Some compounds of bromine are used for medical purposes (p. 330)
brontosaurus (brŏn tō sô′rus). One of the largest of the prehistoric reptiles; a species of dinosaur (p. 407)
Brown, Robert. One of the greatest of the English botanists (1773–1858). He discovered the nucleus in cells (p. 482)
buoy (boi) **up.** To keep afloat (p. 283)
buzzard. A large bird belonging to the eagle family, with powerful wings, a stout hooked bill, and strong claws. It feeds chiefly on the bodies of dead animals (p. 263)

calcium (kăl′sĭ um). A white metal; an element whose compounds are common in nature. Chalk, shells, limestone, and marble are composed chiefly of calcium carbonate ($CaCO_3$) (p. 45)
calcium bicarbonate (bī kär′bon āt). $Ca(HCO_3)_2$, a compound of calcium, carbon, hydrogen, and oxygen. It is soluble in water and is formed when calcium carbonate unites with carbonic acid (p. 332)
calcium carbonate. $CaCO_3$, a compound of calcium, carbon, and oxygen. Limestone, marble, and shells of such sea life as oysters, clams, and coral are forms of calcium carbonate (p. 332)
calyx (kā′lĭks). The outer covering of a flower, usually green (p. 220)
capillary (kăp′ĭ lā rĭ) (*pl.* **capillaries**). A tiny blood tube with thin walls through which food and gases pass to or from the body cells (p. 511)
carbon. An element which is part of many compounds. Charcoal and coal are impure forms of carbon. All living material contains carbon (p. 386)
carbon dioxide. CO_2, one of the gases of the air (0.04 per cent), is necessary for plants in food-making and is a product of respiration and burning (p. 154)
carbonates (kär′bon āts). Compounds of a metal with carbon and oxygen. The carbon and oxygen are always in one or more groups each of which is composed of one atom of carbon and three of oxygen. Washing soda, baking soda, marble, and limestone are carbonates (p. 476)
carbonic (kär bŏn′ĭk) **acid.** The acid contained in a solution of carbon dioxide in water(p. 332)
Carboniferous (kär bon ĭf′ẽr us) **period.** One of the early periods of the geological age, during which occurred the growth of great amounts of vegetation which later became coal. The Carboniferous period occurred in the latter half of the Paleozoic era (p. 400)
carnivorous (kär nĭv′ō rus). Feeding only on flesh (p. 402)
cellophane (sĕl′ō fān). A transparent material made from cellulose and used a great deal as a protective wrapping for food and other things (p. 229)
cellulose (sĕl′ū lōs). The chief indigestible portion of plants. Cellulose is a carbohydrate (p. 440)
Cenozoic (sē nō zō′ĭk). The most recent of the five great geological eras

into which geologists divide the earth's history. We are living in the Cenozoic era (p. 377)

centigrade. A thermometer scale whose markings are made so that there are 100 degrees between the freezing (0° C.) and boiling (100° C.) points of water (p. 153)

centimeter (sĕn′tĭ mē tẽr). One hundredth of a meter. A centimeter equals 0.3937 inch, that is, a little more than one third of an inch (p. 166)

centrifugal (sĕn trĭf′ū ga̱l) **force.** The force which tends to cause a body which is moving in a curved path to fly off in a straight line (p. 40)

chemical equation (ē kwā′shu̱n). A statement using chemical formulas to show a chemical change (p. 332)

chemical formula (fôr′mu la̱). A letter or group of letters and numbers representing the chemical composition of a substance (p. 332)

chlorides (klō′rīdz). Compounds of a metal with chlorine. Ordinary table salt is a chloride; sodium chloride (p. 476)

chlorine (klō′rĭn). A heavy, greenish-yellow, poisonous gas (p. 330)

chlorophyll (klō′rō fĭl). The green coloring matter of plants (p. 214)

chloroplasts (klō′rō plăsts). Small bodies within the cells of green plants; they contain the chlorophyll (p. 471)

chrysalis (krĭs′a̱ lĭs). The final stage through which some insects, such as butterflies, pass before reaching the adult or winged state; the same as pupa (p. 245)

cilia (sĭl′ĭ a̱) (*sing.* **cilium**). Fine hairlike threads of protoplasm found on some one-celled animals and on certain tissues in higher animals (p. 475)

circulation (sẽr kū lā′shu̱n). Movement from and back to a starting point. For example, the movement of blood from the heart through the blood vessels of the body and back to the heart again. Applied also to movement of air within a room or over the earth (p. 204)

classify (klăs′ĭ fī). To arrange in classes. To determine to which group a plant or animal belongs (p. 221)

climatic (klī măt′ĭk) **zones.** Five zones bounded by lines parallel to the equator and named according to the prevailing climate (p. 108)

clockwise. In the same direction that the hands of a clock move (p. 188)

club mosses. Low, bushy, or fingerlike plants, covered with scale leaves. They grow commonly in moist woods, and they are not mosses but belong with the horsetails in the group known as the "fern allies." One type of club moss is called the ground pine and is often used in making Christmas wreaths (p. 385)

cobalt (kō′bôlt). A steel-gray metal. Some of its compounds are a deep blue (p. 39)

cœlenterates (sē lĕn′tẽr āts). A large group of water animals whose bodies consist mainly of a hollow "stomach," armed with numerous tentacles around the mouth. Sea anemones, jellyfish, and corals are examples of cœlenterates (p. 280)

composition. The materials of which a substance is made (p. 4)

concentrated (kŏn′se̱n trāt′e̱d) **foods.** Foods high in energy value (p. 486)

concentration (kŏn se̱n trā'shu̱n). Strength, amount (p. 458)
concentric (ko̱n sĕn'trĭk). Having a common center. Concentric circles are circles drawn about the same center (p. 185)
condensation (kŏn dĕn sā'shu̱n). The process of changing from a gas to a liquid form, as when water vapor or steam is condensed to form water (p. 176)
Continental Divide. In the Rocky Mountains a line dividing the river system that drains east and into the Gulf of Mexico from the river systems that drain west and into the Pacific Ocean (p. 184)
convection (ko̱n vĕk'shu̱n). The transfer of heat by the movement of molecules of liquids and gases (p. 116)
convection currents. Currents in liquids or gases caused as the warmer and less-dense fluid is forced upward by colder and denser material (p. 116)
Copernicus (kō pẽr'nĭ ku̱s), **Nicolaus.** A Polish astronomer (1473–1543) who first taught that the sun was the center of the solar system (p. 24)
coral reef. A ridge of coral built up from the sea bottom and lying level with or just below the surface of the water. It is made of the hard skeletons of certain small sea animals (p. 281)
corolla (kō rŏl'a̱). The inner floral envelope of a flower, consisting of one or more petals and usually brightly colored (p. 220)
corona (kō rō'na̱). The brilliant rim of light that surrounds the sun, observed during a total solar eclipse (p. 75)
corpuscle (kôr'pŭs 'l). A small living cell in the blood. There are two kinds, white and red. The white ones destroy germs, and the red ones carry oxygen (p. 473)
cosmic (kŏz'mĭk) **rays.** Radiation of very short wave lengths which reaches the earth from outer space. The effects of these rays have only recently been studied (p. 443)
counteract (koun tẽr ăkt'). To act against so as to defeat or hinder (p. 303)
counterclockwise. In the opposite direction from which the hands of a clock move (p. 186)
Cro-Magnon (krō mȧ nyôn') **man.** One of the early races of man, possessing a fairly high level of culture and intelligence and superior to the earlier races such as Neanderthal and Piltdown man (p. 420)
cross-pollination (krŏs pŏl ĭ nā'shu̱n). The transfer of pollen from the stamen of one flower to the pistil of another (p. 222)
cycad (sī'kăd). A type of seed-bearing tropical plant. It is the living relative of the most ancient of all seed plants which flourished in the warm, moist climate of the Paleozoic era (p. 385)
cycle (sī'k'l). A continuous process which is constantly repeated. In biology the life cycle of a plant or animal (p. 212). In physics often used to mean the same as *frequency.* The number of cycles per second will be equal to the frequency (p. 452)
cyclone. Winds rotating around a center of low atmospheric pressure. A cyclone is not violent, one passing over the United States every two or three days (p. 185)
cyclonic (sī klŏn'ĭk). Resembling or having to do with a cyclone (p. 167)

dahlia (däl'ya̤). A common garden plant whose large, showy blossoms are composed of numerous small flowers clustered in a head (p. 279)
deflect (dē flĕkt'). To bend or turn aside from a straight line (p. 118)
delicate. Easily affected; fine and accurate (p. 375)
density (dĕn'sĭ tĭ). The closeness or compactness of matter in any substance. The weight of a unit volume (p. 35)
dike. A mass of igneous rock which has flowed into a crack, cutting across the layers of the inclosing rocks (p. 366)
dinosaur (dī'nō sôr). A member of a group of extinct reptiles living during the Mesozoic era (p. 377)
diplodocus (dĭp lŏd'ō ku̯s). One of the largest of the dinosaurs. It fed on plants, had a long slim neck and head and a long tail (p. 427)
distilled (dĭs tĭld') **water.** Water which has been changed to steam and condensed; impurities are left behind (p. 228)
doldrums (dŏl'dru̯mz). The region under the vertical rays of the sun, often called the equatorial belt of calms (p. 120)
dry ice. Carbon dioxide in solid form (p. 51)
duct. A tube through which secretions may flow from one part of the body to another (p. 490)

eelgrass. A common water plant which grows on muddy river bottoms in shallow water. Its leaves are long and tapelike or eel-like in appearance. The flowers are borne on long coiled stalks (p. 279)
egg nucleus (nū'klē u̯s). The nucleus within the unfertilized ovule which, upon uniting with a sperm nucleus, forms the fertilized egg (p. 222)
elasticity (ē lăs tĭs'ĭ tĭ). The power of an object to resume its original shape after being bent, twisted, squeezed, etc. (p. 358)
electron (ē lĕk'trŏn). In the electron theory the electron is considered to be a particle of negative electricity (p. 430)
electron theory. A theory which teaches that electricity is of two kinds. These are called negative particles (electrons) and positive particles (protons). These two kinds of particles taken together compose atoms
Elodea (ē lō'dē a̤). A common water plant (p. 477)
embryo (ĕm'brĭ ō). The young of an animal in its earliest stages of development, that is, unborn or unhatched (p. 223)
energy (ĕn'ẽr jĭ). A thing has energy if it can exert a push or a pull. Light, heat, and electricity are forms of energy. Anything which is moving has energy (p. 429)
engineering. The science and art of erecting and using machinery, including bridges, tunnels, skyscrapers, etc. (p. 296)
environment (ĕn vī'ru̯n me̯nt). The things and forces which surround us (p. 6)
enzyme (ĕn'zīm). A substance which brings about chemical changes within living organisms, but which is not itself used up. Thus a small amount of an enzyme will be able to bring about a large amount of chemical change (p. 487)
equinox (ē'kwĭ nŏks). The time when the earth is not inclined on its axis either toward or away from the sun, and the sun's rays fall as much on one pole as on the other. This occurs on September 21 and March 21,

and at these times day and night are of equal length everywhere on the earth (p. 93)

erepsin (ē rĕp′sĭn). An enzyme secreted by glands in the walls of the intestine; it aids in digestion of proteins (p. 499)

ergosterol (ẽr gŏs′tẽr ōl). A substance in the skin that takes on properties of vitamin D when exposed to sunlight (p. 458)

erosion (ē rō′zhu̥n). The gradual wearing down of the earth's surface. The loosening and carrying away of rock by wind, water, or glaciers (p. 367)

esophagus (ē sŏf′a̤ gu̥s). The food tube leading from the mouth to the stomach (p. 488)

Euglena (ū glē′na̤). A small one-celled organism. *Euglena* contains chlorophyll, but also is very similar to one-celled animals (p. 482)

excrete (ĕks krēt′). To give off, as waste matter, outside the body (p. 490)

excretion (ĕks krē′shu̥n). A waste product thrown off by an organism (p. 238)

experimental method. The method of learning and proving by experimenting. Experiments are used to test ideas to see if they are true (p. 470)

exposure (ĕks pō′zhūr). The length of time that the shutter of a camera is open. Light rays reflected from the scene or object being photographed are allowed to strike the photographic film (p. 21)

Fahrenheit (fä′re̥n hīt). A thermometer scale whose markings are made so that there are 180 degrees between the freezing and boiling points of water. Water freezes at 32° F. and boils at 212° F. (p. 171)

fatty acids. Acids formed from fats, as in the process of digestion (p. 495)

fault. A crack in the earth's crust along which slipping has taken place (p. 364)

faulting. The process by which faults, or cracks, are produced in rocks (p. 371)

fertilized (fẽr′tĭ līzd) **egg.** The cell formed by the union of the egg nucleus and the sperm nucleus (p. 223)

filth. Dirty or impure matter, such as manure, garbage, and so forth (p. 235)

firmament (fẽr′ma̤ me̥nt). Wide extent of the heavens in which the stars were supposed to be set, according to the teachings of Ptolemy (p. 23)

fossilized (fŏs′ĭl īzd) Remains or traces of once living organisms which have become changed into rock material (p. 408)

Franklin, Benjamin. A great American (1706–1790) prominent in affairs of government and in science (p. 167)

frequency (frē′kwe̥n sĭ). The number of vibrations per second. The number of waves that pass a given point in a second (p. 450)

function (fŭŋk′shu̥n) **(functioning).** The work or duty of any organ in a plant or animal (p. 299)

fungi (fŭn′jī) (*sing.* **fungus** (fŭŋ′gu̥s)). Plants with no green coloring matter. These plants cannot make their own food but must live upon other living or dead organisms. Mushrooms, toadstools, and puffballs are fungi (p. 476)

gall (gôl) **bladder.** A small organ located beneath the liver. It stores secretions from the liver. These pass from the gall bladder into the small intestine (p. 488)

gaseous (găs′ē us). In the form of a gas (p. 437)

gastric glands. Glands in the walls of the stomach (p. 487)

generate (jĕn′ẽr āt). To produce, as to generate steam in a boiler (p. 288); to generate heat, light (p. 361)

genus (jē′nus) (*pl.* **genera** (jĕn′ẽ ra)). A group of animals or plants having certain common traits and resembling each other fairly closely. A genus contains several species. *See* species

geological (jē ō lŏj′ĭ kal). Having to do with geology (p. 315)

geologist (jē ŏl′ō jĭst). A scientist who specializes in geology (p. 317)

geology. The study of the history and formation of the earth as shown by the rocks (p. 317)

Gila (hē′la) **monster.** A desert lizard sometimes as much as two feet in length, having a very poisonous bite (p. 264)

glacial (glā′shal) **action.** The scouring or wearing action caused by the movement of a glacier (p. 386)

glacial drift. Glacial remains; a collection of loose earth rocks and bowlders carried from a distance by means of a glacier (p. 346)

glucose (gl o͞o′kōs). A simple sugar formed during the digestion of carbohydrates (p. 484)

gluten (glo͞o′tĕn). One of the protein substances of which flour is composed. Its presence is what makes dough sticky (p. 498)

glycerin (glĭs′ẽr ĭn). A compound of carbon, hydrogen, and oxygen, $C_3H_5(OH)_3$. It is a rather thick liquid often used to soften the skin (p. 495)

glycogen (glī′kō jĕn). The form of carbohydrate in which food is stored in the liver. It is similar to starch, only formed in animal tissues rather than plant tissues (p. 490)

grain. A unit of weight used for small quantities. There are 437.5 grains in an ounce (p. 173)

gram. The weight of 1 cubic centimeter of water at its greatest density. There are 28.4 grams in an ounce or 454.6 grams in a pound (p. 389)

granitic (gra nĭt′ĭk). Of the nature of granite (p. 360)

gravitation (grăv ĭ tā′shun), **the laws of.** The laws of gravity. These laws describe how objects move under the influence of the force of gravity (p. 36)

gravitational (grăv ĭ tā′shun al) **attraction or force.** The attraction between two objects due to gravity (p. 83)

gravity. The attraction of two bodies for each other due to their mass. There is an attraction between the earth and bodies on or near its surface. There is an attraction between the earth and the sun and between other heavenly bodies (p. 40)

habitat (hăb′ĭ tăt). The place where a plant or animal naturally lives (p. 262)

haddock (hăd′uk). A sea fish of the cod family, common in the north Atlantic

Halley's (hăl'ĭz) **comet.** A comet which appears regularly after a period of not quite seventy-six years. It is named after Halley, an English astronomer (1656–1742), who saw it in 1682 and predicted its return in 1758 (p. 34)

haze. A slight fog or mist (p. 5)

head winds. Winds opposite to the direction an object is moving. Head winds oppose the forward motion of a ship (p. 115)

headwaters. Waters at the source, or "head," of a river (p. 137)

Heidelberg (hī'dẹl bẽrg) **man.** One of the earliest of the human race. The fossil remains were discovered near Heidelberg, Germany (p. 415)

helium (hē'lĭ ụm). A light, colorless element in the form of a gas. Used in the United States for filling dirigibles (p. 46)

Helmont, Jean Baptiste van (văn hĕl'mŏnt). Flemish scientist (1577–1644). One of the first to use the experimental method in the study of plant growth (p. 469)

hepatica (hē păt'ĭ kạ). A plant having heart-shaped leaves with three divisions, somewhat resembling the liver; therefore sometimes called liverleaf (p. 225)

herbivorous (hẽr bĭv'ō rụs). Feeding only on plants (p. 402)

heron (hĕr'ụn). A long-legged, long-necked wading bird (p. 232)

high. An area of high atmospheric pressure (p. 206)

Hooke, Robert. An English botanist (1635–1703). He discovered that plants are built of cells (p. 482)

horse latitudes. Two regions or belts of high pressure extending around the earth at about the thirtieth (30 degrees) parallel north and the thirtieth parallel south of the equator. The winds which blow toward the equator from these regions are called the trade winds (p. 119)

horsetails. Leafless plants with hollow and rushlike stems; the horsetails belong to a group of plants related to the ferns (p. 385)

Humboldt, Alexander von (vŏn hŭm'bōlt). One of the world's greatest travelers; a German by birth (1769–1859) (p. 140)

hybrid (hī'brĭd). An animal or plant which is produced by breeding together two different species or varieties of organisms (p. 221)

hygrometer (hī grŏm'ē tẽr). An instrument used to measure the amount of moisture in the air (p. 165)

hypothesis (hī pŏth'ē sĭs). A reasonable explanation set up for the purposes of experimentation and testing, which has not yet been tested so completely as to be called a theory (p. 461)

igneous (ĭg'nē ụs). Formed when molten material solidifies (p. 366)

igneous rocks. Rocks which have been made by the cooling and solidifying of hot molten matter from deep within the earth. Granite is an igneous rock (p. 359)

impulse (ĭm'pŭls). Blow, collision (p. 455)

inclination (ĭn klĭ nā'shụn). The slope or slant of a line or plane from the vertical position (p. 54)

inelastic. The opposite of elastic; will not return to its original shape after having been stretched or in some other way forced out of shape (p. 360)

infra-red. Radiations of longer wave length than the waves of red light. Much of the energy of infra-red radiation which falls upon any object is changed into heat (p. 443)

inject (ĭn jĕkt′). To introduce or force a fluid into something by mechanical means (p. 307)

instantaneous (ĭn stan tā′nē us). Acting instantly; taking place without any noticeable passing of time (p. 444)

interferometer (ĭn tẽr fēr ŏm′ē tẽr). An instrument used in the study of light; it may be used to measure the diameter of a star (p. 447)

interglacial periods. Periods or intervals between the advances of the glaciers, when the climate grew warmer and the glaciers receded. There were three interglacial periods during the Glacial Age, in the latter part of the Cenozoic era (p. 414)

intersect (ĭn tẽr sĕkt′). To divide a thing by crossing it. For example, lines intersect each other (p. 89)

isobar (ī′sō bär). A line connecting places on the earth's surface having the same air pressure (p. 185)

isotherm (ī′sō thẽrm). A line connecting those places on the earth's surface which have the same temperature (p. 188)

Java (jä′va) **man.** One of the earliest of human beings. The fossils of this primitive man were found on the island of Java and date back about a million years, to a time before the glacial period (p. 415)

killer whale. A very fierce, though one of the smaller, species of whales. It kills fish, seals, and other whales (p. 276)

kilocycle. A thousand cycles (p. 452). *See* cycle

kilogram-calorie (kĭl′ō grăm kăl′ō rĭ). The amount of heat needed to raise 1 kilogram of water 1° C. (p. 494)

kilometer (kĭl′ō mē tẽr). A thousand meters. About six tenths of a mile (p. 460). *See* meter

laboratory (lăb′ō ra tō rĭ). A workroom equipped for studying science by careful tests and experiments (p. 375)

ladle (lā′d'l). A long-handled, deep spoon used for transferring liquids (p. 44)

life cycle. A round of events or stages in the life of an organism (for example, egg–larva–pupa–adult–egg), proceeding in regular succession (p. 223)

light year. The distance light travels in a year. It is about six million million (6,000,000,000,000) miles (p. 462)

light-struck. A film or print spoiled by accidental exposure to light is said to be light-struck (p. 453)

lime. Calcium oxide (quicklime), but also sometimes loosely used for calcium carbonate (limestone, marble, shells) (p. 281)

Linnæus (lĭ nē′us), **Carolus.** A Swedish botanist (1707–1778); the first to introduce system into the study of the plant world (p. 221)

lipase (lĭp′ās). Contained in the pancreatic juice; an enzyme which aids in the digestion of fats (p. 494)

low. An area of low atmospheric pressure (p. 206)
lunar (lū′na̤r). Depending upon or caused by the moon (p. 67)

maggot (măg′o̤t). The larva of a fly (p. 235)
magnesium (măg nē′zhĭ u̇m). One of the metallic elements, silver-white in appearance. Its compounds are of common occurrence in nature. Magnesium burns rapidly in air, giving a blue-white light. It is often used in flashlight powders (p. 45)
magnetic (măg nĕt′ĭk). Having to do with, resembling, or acting like a magnet (p. 387)
mammal (măm′a̤l). A member of a group of animals which nurse their young (p. 250)
marine (ma̤ rēn′). Of, or having to do with, the sea (p. 343)
mathematical (măth ē măt′ĭ ka̤l). Having to do with mathematics (p. 27)
mathematical equation (ē kwā′shu̇n). A statement used in mathematics to express the fact that two quantities or expressions are equal (for example: $4 + 2 = 3 + 3$) (p. 27)
mercury-vapor lamp. A lamp in which the light is given off by a current of electricity passing through a glass tube of mercury vapor. The light is bluish (p. 459)
Mesozoic (mĕs ō zō′ĭk). One of the five great eras into which geologists have divided the earth's history (p. 377)
mesquite (mĕs kēt′). A shrub having fragrant flowers and sugary pods. It is common in the desert regions of the Southwestern states and Mexico (p. 262)
metallic (mē tăl′ĭk). Consisting of, or like, a metal (p. 173)
meteoric (mē tē ŏr′ĭk) **matter.** The matter of which a meteor is composed (p. 37)
meteorite (mē′tē o̤r īt). A body, composed of stone or metal, which has fallen to the earth from outer space (p. 37)
meter (mē′tẽr). The unit of measure of length in the metric system. It is equal to 39.37 inches (p. 449)
metric (mĕt′rĭk) **system.** A system of measurement based upon counting by tens. The meter, the liter, and the gram are the units of length, volume, and weight (p. 166)
Michelson (mī′ke̤l su̇n), **Albert.** A famous American scientist (1852–1931) who made accurate measurements of the speed of light and measured the diameter of stars (p. 447)
millimeter (mĭl′ĭ mē tẽr). One thousandth of a meter (p. 449). *See* meter
mineral salts. Compounds of a metal with other elements. Certain mineral salts are necessary to growth and health of living things (p. 474)
mineral substances. Substances which are not and never have been directly a part of living things. Usually such things as metals, rocks, soil, etc. (p. 479)
Mohl, Hugo von (fōn mōl′). A German botanist (1805–1872). He was noted for the accuracy of his observations, drawings, and descriptions (p. 482)

molecule (mŏl′ē kūl). The smallest quantity of any substance which can exist separately and still keep its composition and properties, or qualities (p. 51)
mullein (mŭl′ĭn). A tall stout weed, a biennial (p. 212)
mumbo jumbo. A West African idol; meaningless incantation; mummery (p. 159)
mussel. A water animal with a soft body covered by two shells. Some mussels are used for food (p. 277)

narcotic (när kŏt′ĭk). A substance or drug which tends to slow down heart action and bring about sleepiness and unconsciouness (p. 519)
Neanderthal (nā än′dẽr täl) **man.** One of the earlier races of primitive man, living during the third interglacial period. The remains of the first Neanderthal man were found in a cave near Neanderthal, Germany (p. 418)
nectar (nĕk′ta̱r). The sweet liquid produced by flowers, from which bees make honey (p. 220)
Neolithic (nē ō lĭth′ĭk) **Age.** The New Stone Age; an age in the development of primitive man when the stone weapons and implements were better and more skillfully made (p. 419)
nostrum (nŏs′tru̱m). A fake remedy or patent medicine (p. 310)
nucleus (nū′klē u̱s) A small central kernel. In biology, the portion of a cell which contains the mechanism that controls its growth and division (p. 471). In physics, the central core of the atom (p. 457)

observatory (o̱b zẽr′va̱ tō rĭ). A building equipped with telescopes and other apparatus for studying the heavens; a place where astronomers make observations (p. 21)
octopus (ŏk′tō pu̱s). A large sea animal with eight long arms covered with suckers. It is closely related to the squid, but is found only in southern seas. The most common octopus is known as the devilfish (p. 285)
organism (ôr′ga̱n ĭz′m). A living thing (p. 276)
ovule (ō′vūl). An undeveloped seed (p. 222)

Paleolithic (pā lē ō lĭth′ĭk) **Age.** The Old Stone Age; the earlier stage in the development of primitive man, when the stone weapons and tools were rudely and roughly made (p. 419)
Paleozoic (pā lē ō zō′ĭk). The middle one of the five great eras into which geologists divide earth history (p. 327)
pancreas (păŋ′krē ăs). A large gland which secretes substances that aid in digestion, located just below the stomach (p. 487)
Paramecium (păr a̱ mē′shĭ u̱m). A one-celled animal commonly found in stagnant water (p. 473)
particle. A very small amount of substance (p. 318)
Pasteur (pȧs tẽr′), **Louis.** A French chemist and biologist (1822–1895) (p. 482)
peat (pēt). A kind of turf commonly found in bogs and formed of the compressed, partly decayed roots and fibers of plants, especially bog plants (p. 386)

Peking man. One of the earliest of the human race; the skeletons of Peking man were found near Peking, China, and date back about a million years, to a time before the glacial period (p. 415)

penguin (pĕn'gwĭn). A short-legged water bird found in the Southern Hemisphere. Penguins cannot fly, but they are powerful swimmers (p. 272)

pepsin. An enzyme secreted by the glands in the stomach; it starts the digestion of proteins (p. 499)

perennial. A plant which continues to live season after season, sometimes for many years (p. 227)

periwinkle. An edible shellfish resembling a small snail, commonly found on the north Atlantic seashore (p. 277)

perpendicular (pẽr pe̱n dĭk'ū la̱r). Perfectly upright or erect; standing at right angles to a given line or surface (p. 97)

petrified (pĕt'rĭ fīd). Changed from organic to inorganic material by the gradual replacing, molecule for molecule, of mineral salts for the original plant or animal tissue (p. 412)

phases (fāz'ĕz). States of the moon (such as new moon, full moon, etc.) or of a planet with regard to the amount of lighted surface which can be seen (p. 28)

phenomenon (fē nŏm'ē nŏn) (*pl.* **phenomena** (fē nŏm'ē na̱)). A happening, or event, especially one which illustrates a scientific law (p. 185)

phosphates (fŏs'fāts). Compounds of a metal with phosphorus and oxygen. The phosphorus and oxygen are always in one or more groups, each of which is composed of one atom of phosphorus and four atoms of oxygen. Certain phosphates are important as fertilizers (p. 476)

phosphorus (fŏs'fo̱r u̱s). One of the chemical elements (p. 459)

photosynthesis (fō tō sĭn'thē sĭs). The process by which carbohydrates are manufactured in the green cells of plants in the presence of sunlight (p. 218)

Piltdown man. One of the earlier races of primitive man, living in the third interglacial period. The fossil remains of the Piltdown man were found in an old river bed near Piltdown in Sussex, England (p. 415)

pith. Soft, spongy tissue in the center of the stem of a plant (p. 477)

plane. A surface that is level or flat (p. 24)

planetoids (plăn'ĕt oidz). Astronomical bodies resembling planets but much smaller, which are distributed in space between the orbits of Mars and Jupiter (p. 25)

political geography. Geography concerned with the boundaries of states etc. (p. 315)

pollack (pŏl'a̱k). A sea fish of the cod family, commonly found in the north Atlantic

porous (pō'ru̱s). Containing pores or holes (p. 332)

portal vein. A large vein which carries blood rich in digested food materials from the small intestine to the liver (p. 488)

potassium (pō tăs'ĭ u̱m). A soft, white metal; a chemical element (p. 45)

potholes. Holes which have been worn in rock by running water (p. 320)

prawn. An edible shellfish which looks like a large shrimp (p. 279)

praying mantis. An insect resembling a huge grasshopper; its position

while waiting for its victims seems to be that of prayer. It eats other insects which are caught in its powerful forelegs (p. 241)

precipitation (prē sĭp ĭ tā'shu̥n). The falling of snow, rain, or hail (p. 58)

primum mobile (prī'mŭm mŏb'ĭ lē). Latin for "the first movable"; applies to the outermost of the movable spheres of which the world was made, according to the teaching of Ptolemy (p. 23)

property. A quality of an object. For example, sweetness is a property of sugar, wetness is a property of water, and hardness is a property of iron

Proterozoic (prŏt ẽr ō zō'ĭk). The second (commencing with the oldest) of the five great eras into which geologists divide the earth's history (p. 326)

protoplasm (prō'tō plăz'm). The contents of living cells (p. 471)

ptyalin (tī'a̤ lĭn). An enzyme, found in the saliva, which changes starch to sugar (p. 489)

quartz (kwôrts). A hard, common mineral composed of silicon and oxygen. Quartz may be colored or colorless. Sand is largely quartz. Pure quartz is transparent

quartzite. A rock composed of quartz, or sand grains, so firmly cemented that when the rock is broken it breaks through the grains instead of around them. Quartzite is usually formed when sandstone is subjected to great heat or pressure (p. 418)

radiant (rā'dĭ a̤nt) **energy.** A form of energy which travels through empty space with the speed of light. Radio waves and radiation from the sun are common forms of radiant energy (p. 47)

radiation (rā dĭ ā'shu̥n). Rays from a luminous or heated body. Radiation comes to the earth from the sun (p. 62)

reforestation (rē fŏr ĕs tā'shu̥n). Caring for forests and planting of new trees in such a way that the forests are not destroyed as the older trees are cut for lumber or fuel (p. 348)

relative humidity. The relation between the amount of water vapor really present in a space at any one time and the amount that would be present if the space were saturated with moisture (p. 174)

resistance (rē zĭs'ta̤ns). The power successfully to oppose or prevent an attack of disease etc. (p. 299)

respiration (rĕs pĭ rā'shu̥n). The process of taking air into the cells, using it in the production of energy, and expelling the waste product (p. 255)

retina (rĕt'ĭ na̤). The inner coat of the eye; it is easily affected by light and receives the image (p. 458)

rhododendron (rō dō dĕn'dro̥n). A kind of evergreen shrub with thick glossy leaves and large handsome flowers which may be white, pink, or lavender (p. 259)

rickets. A disease marked by softening of the bones, caused by lack of vitamin D in the diet (p. 458)

ring stand. A metal stand with a flat base fixed with a round metal rod to which objects are attached for support (p. 166)

roadbed. The bed or foundation, usually of gravel, upon which the ties and rails of a railroad are laid (p. 415)

rockweeds. Simple plants (seaweeds) found commonly along the sea-

coast, attached to rocks etc. They possess numerous "bladders," by means of which they float (p. 277)

Römer (rē'mēr), **Olaus.** A Danish astronomer (1644–1710), first to figure the speed of light (p. 444)

saber-toothed tiger. An extinct kind of tiger having a pair of large curved teeth (p. 419)

saguaro (sa̤ gwä'rō). Giant form of cactus; state flower of Arizona (p. 260)

salamander (săl'a̤ măn dẽr). One of the amphibians which resembles a lizard (p. 234)

sand hoppers. Tiny animals related to shrimps, crabs, etc.; they are common along sandy beaches between the tide-marks. They are often called sand fleas (p. 278)

sand-blasting. A process in which sand is driven by a stream of air or steam. It is used in cutting and polishing glass and other hard substances; also used in cleaning the outside walls of brick and stone buildings (p. 336)

sandstone. A sedimentary rock formed by the cementing together of sand grains (p. 359)

Sargasso (sär găs'ō) **Sea.** A stretch of calm waters lying between the waters of the Gulf Stream, flowing toward the northeast, and the ocean current flowing toward the southwest. No strong ocean currents flow outward from the Sargasso Sea, and therefore seaweed that floats into it is likely to remain there (p. 282)

sargassum (sär găs'u̇m). Seaweed occurring as floating masses in the Sargasso Sea (p. 283)

satellite (săt'e̤ līt). A smaller heavenly body which revolves about a larger one. The moon is a satellite of the earth (p. 32)

scallop (skŏl'u̇p). A small shellfish with nearly circular shells the edges of which are in the form of a succession of curves. The muscle which holds the shells together is the part which is eaten (p. 279)

sea anemones (a̤ nĕm'ō nēz). Sea animals with soft jellylike bodies armed with many threadlike tentacles with which they sting and capture their victims. They resemble flowers in appearance (p. 277)

sea urchin. A sea animal with a shell covered with spines. It is related to the starfish and the sand dollar (p. 278)

sedimentary (sĕd ĭ mĕn'ta̤ rĭ) **rocks.** Rocks formed by the cementing together of sediments. Sandstone is a sedimentary rock, formed by the cementing together of sand grains (p. 359)

seismograph (sīs'mō gra̤f). An instrument which records the earth's vibrations, even at great distances, caused by an earthquake (p. 362)

sensitive (sĕn'sĭ tĭv) **to light.** Capable of being changed chemically by the action of light (p. 454)

sequoia (sē kwoi'a̤). An evergreen tree of immense size; the well-known redwood trees of California

shale. A sedimentary rock formed from mud sediments or clay. It can be easily split into thin slabs (p. 359)

Shetland pony. A very small breed of horse. The full-grown adult is only about three feet high (p. 411)

short wave. Usually applied to the shortest waves used in broadcasting. These are within the range of 20 to 100 meters in length (p. 462)
silicon (sĭl'ĭ kŏn). Next to oxygen, silicon is the most abundant chemical element in the earth's crust (p. 45)
sill. A mass of igneous rock which has flowed between layers of the inclosing sedimentary rocks (p. 366)
silt. Sediment deposited by running water (p. 323)
silver bromide. A compound of silver and bromine used in the light-sensitive coating of photographic films (p. 453)
sinus (sī'nu̱s). A cavity located in one of the bones of the skull and opening into the nose. There are four of these sinuses. Often infection may develop in these cavities (p. 302)
sodium (sō'dĭ u̱m). A metallic chemical element, soft and silvery-white in appearance. Its compounds are widely distributed. Salt, washing soda, and baking soda are common sodium compounds (p. 45)
sodium chloride (klō'rīd). A compound of sodium and chlorine; table salt (p. 329)
solar (sō'la̱r) **radiation.** Rays from the sun (p. 277)
solstice (sŏl'stĭs). Means "the standing still of the sun." June 21 is the *summer solstice.* At this time the noon sun reaches its highest point in the northern heavens. December 21 is the *winter solstice.* At this time the sun has reached its highest point in the southern heavens (p. 90)
specialization (spĕsh a̱l ĭ zā'shu̱n). The carrying on of only one kind of work or activity (p. 479)
species (spē'shēz) (*pl.* **species**). A particular kind or type of organism. Members of the same species resemble each other rather closely, but differ from other species of the same genus. For example, the cat flea is one species, the human flea another species, but both belong to the same genus
sperm nucleus. One of the nuclei within a pollen grain; it unites with the egg nucleus to form the fertilized egg (p. 222)
spleen. An organ lying near the stomach; it stores blood during times of low bodily activity and releases it when needed if the body becomes active (p. 513)
squid. A cuttlefish, a peculiar animal of the sea with an internal shell, eight arms, and two tentacles, covered with suckers, and two large eyes. It possesses an ink sac containing a dark fluid which it uses in escaping from its enemies (p. 285)
stalactites (sta̱ lăk'tīts). Calcium carbonate rock (limestone) hanging like icicles from the roofs of limestone caves (p. 333)
stalagmites (sta̱ lăg'mīts). Spikes of pure limestone which rise from the floor of limestone caves. They are formed by drippings from the roofs of these caves (p. 333)
stegosaurus (stĕg ō sô'ru̱s). One of the large dinosaurs. It had a very short neck, small head, and a ridge of very large horny plates along its back (p. 427)
stentor (stĕn'to̱r). A one-celled animal with a ring of strong cilia around the mouth opening. It is trumpet-shaped when attached and pear-shaped when swimming freely (p. 482)

stigma. The sticky upper part of the pistil, upon which the pollen is caught (p. 222)

stimulant (stĭm'ū la̱nt). A substance or drug which increases heart action and other bodily activity (p. 519)

stoma (*pl.* **stomata** (stō'ma̱ ta̱)). A very small opening through the wall or "skin" of a leaf, through which air and other gases may pass in and out of the leaf and around the cells (p. 219)

stratosphere (strā'tō sfēr). The upper portion of the atmosphere. The temperature changes but little, and no clouds form in the stratosphere (p. 169)

sucrose (sū'krōs). The chemical name for cane sugar (p. 484)

Sudan (so͞o dän'). The grasslands in Africa lying between the Sahara and the jungles (p. 146)

sulfurous (sŭl'fu̱r u̱s). Made of, mixed with, or having the qualities of sulfur. Usually applied to the odor of burning sulfur (p. 352)

sun spots. Dark spots which appear from time to time on the surface of the sun. They seem to have some connection with the number of thunderstorms occurring on the earth (p. 46)

survey (sẽr'vā; *verb,* su̱r vā'). A general overview; to view as a whole (p. 1)

synclines (sĭŋ'klīnz). The troughs or downfolds of folded rocks (p. 368)

tarantula (ta̱ răn'tū̱ la̱). Large spider having a poisonous, though not a deadly, bite (p. 265)

television (tĕl'ē vĭzh u̱n). The process of sending scenes through space by means of radio waves (p. 448)

tentacles (tĕn'ta̱ k'lz). Slender, threadlike organs which serve as organs of touch in some animals; sea anemones and jellyfish possess tentacles (p. 280)

tern. Small shore birds, smaller and slimmer than gulls (p. 229). *See also* arctic tern

theory (thē'ō rĭ). A reasonable explanation of observed phenomena or events, which has stood the test of much experimentation (p. 13)

thermograph (thẽr'mō gråf). An instrument which automatically records changes in temperature (p. 171)

thoracic (thō răs'ĭk) **duct.** A large tube which carries the lymph which collects in it from various parts of the body to the jugular vein, where the lymph again enters the blood stream (p. 488)

tidal bore. A high wave of water caused by the rising tide in the mouths of some rivers. Being hindered by the narrow channel, it rises in a high watery ridge and travels along with great force and noise (p. 82)

tidal flats. Low, flat regions along the seacoast which are covered with water at high tide and left exposed at low tide (p. 81)

tide-tables. A time-table for the tides (p. 88)

trade winds. The winds that blow toward the equator from the horse latitudes (that is, from about the region of the thirtieth parallel north and of the thirtieth parallel south) (p. 119)

transform. To change from one thing into another (p. 456)

transit. The passage of a heavenly body across the sun's disk, that is, the circular face of the sun (p. 140)

transpiration (trăn spĭ rā'shu̯n). Evaporation of water from the leaves of plants (p. 219)

tremor (trē'mo̯r). A slight quiver or trembling (p. 358)

triceratops (trī sĕr'a̯ tŏps). A species of dinosaur having three horns, and a large, long shield covering the neck (p. 427)

trypsin (trĭp'sĭn). An enzyme secreted by the pancreas; it aids digestion by changing the proteins to amino acids (p. 499)

tuber. A thickened, rounded, and fleshy underground stem, as in the white potato (p. 225)

typhoon (tī fo͞on'). A violent hurricane which occurs in the Chinese and Japanese seas (p. 204)

tyrannosaurus (tī răn ō sô'ru̯s). The largest and most vicious of the flesh-eating dinosaurs (p. 427)

unit. A single thing; a related body of material suitable for study (p. 430)

uranium (ū rā'nĭ u̯m). One of the chemical elements; a white metal, occurring in nature chiefly in combination with oxygen (p. 375)

velocity (vē lŏs'ĭ tĭ). Rate of motion in a given direction (p. 162)

verbena. A fragrant flowering plant with pink, white, blue, or purple flowers borne in clusters (p. 262)

Vesuvius (vē sū'vĭ u̯s). A volcanic mountain in Italy (p. 378)

Vorticella (vôr tĭ sĕl'a̯). A one-celled microscopic water animal having a row of cilia around the mouth and a long tendril-like stalk. It may move rapidly by a sudden coiling of its stalk (p. 482)

water vapor. Water in the form of a gas; usually below the boiling point, to distinguish from steam, although the words are sometimes used for each other (p. 125)

waterspout. A column of water drawn up from the sea by a rapidly whirling mass of air (p. 200)

Weather Bureau. A department of the United States government which maintains many stations for collecting information about weather (p. 113)

westerlies. Winds north of the horse latitudes in the Northern Hemisphere and south of the horse latitudes in the Southern Hemisphere. They blow from west to east (p. 120)

whalebone. An elastic, horny substance obtained from the upper jaws of some whales (p. 276)

wind gauge. An instrument for determining wind velocity (p. 179)

worm casts. Small pellets or rolls of waste materials excreted by worms (p. 404)

yellow fever. A tropical fever attended with yellowness of the skin. It is caused by an unknown organism and is spread by the yellow-fever mosquito (p. 240)

yucca (yŭk'a̯). A plant belonging to the lily family, having long pointed leaves and bearing a cluster of white flowers on a tall stalk or spire. It is common in desert regions of the Western states (p. 262)

zein (zē'ĭn). A protein found in corn meal (p. 498)

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